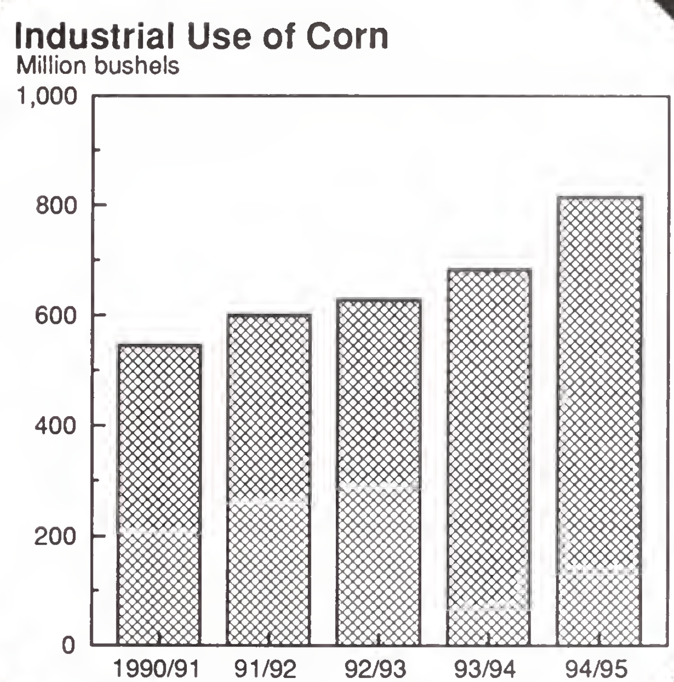
United States
Department of
Agriculture

Economic
Research
Service

IUS-3
June 1994

Industrial Uses Of Agricultural Materials

Situation and Outlook Report



Industrial Uses of Agricultural Materials Situation and Outlook. Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture, June 1994, IUS-3.

Contents

Coordinators

Lewrene Glaser

Gregory Gajewski

Voice (202) 219-0085, Fax (202) 219-0042

Contributors

Gregory Gajewski
Paul O'Connell, AARC Center
David Torgerson
William Edmondson
Douglas Beach
Tom Tice
Allen Baker
Irshad Ahmed, Inst. for Local Self-Reliance
Lewrene Glaser
Alan Weber, Univ. of Missouri
Roger Hoskin
Thomas Marcin, Forest Service
Charles Plummer
Richard Nelson, Kansas State Univ.
Mark Schrock, Kansas State Univ.
Miriam Cygnarowicz-Provost, FDA
Hosein Shapouri, Office of Energy

Statistical Support
David Johnson, (202) 219-0085

Graphics, Table Design, and Layout
Wynnice P. Napper, (202) 219-0884

Word Processing, Design, and Layout
Diana L. Claytor, (202) 219-0085

Approved by the World Agricultural Outlook Board. Summary released June 15, 1994. The next summary of *Industrial Uses of Agricultural Materials Situation and Outlook* is scheduled for release on December 14, 1994.

Summaries and text may be accessed electronically through the USDA CID System; for details, call (202) 720-5505. See back cover for subscription information.

Acknowledgements

This report was made possible through the active support of many people and organizations. The June and December 1994 issues are primarily funded by contributions from the Department of Energy's Office of Industrial Technologies, USDA's Alternative Agricultural Research and Commercialization Center, Cooperative State Research Service, Office of Agricultural Materials, and Agricultural Research Service. Thomas Marcin, an economist from USDA's Forest Service, wrote a section of the report. Donald Van Dyne, Professor of Economics at the University of Missouri, and Irshad Ahmed, Senior Research Engineer of Biochemical Technologies of the Institute for Local Self-Reliance (Washington, DC), also contributed to this report.

Summary

Strong Economic Growth and Environmental Regulation Boost Industrial Uses of Agricultural Materials

Projects funded by USDA's Cooperative State Research Service, Office of Agricultural Materials, are expanding markets for industrial oilseeds, such as crambe and lesquerella, and hypoallergenic latex and other products from guayule. USDA's Alternative Agricultural Research and Commercialization Center has selected 20 projects from the 160 proposals submitted for funding in fiscal year 1994. The projects funded in fiscal 1993 have begun to penetrate and expand targeted markets.

USDA's Agricultural Research Service (ARS) continues to expand its technology transfer activities. In fiscal 1993, ARS more than doubled the number of agreements signed with industry to develop ARS technology. Projects at the U.S. Department of Energy (DOE) are developing high-volume chemicals from biomass. DOE's Office of Industrial Technologies recently completed a technical and market analysis of the current top-50 commodity chemicals produced in the United States. The analysis is being used to evaluate research and development opportunities for using biomass feedstocks.

The consensus of private forecasters is that the U.S. Gross Domestic Product will grow 3.6 percent in 1994. Because of strong economic growth and continued implementation of the Clean Air Act Amendments of 1990 (CAAA), corn use to produce industrial starch and fuel alcohol is forecast at 683 million bushels in 1993/94, up almost 9 percent from 1992/93. In 1994/95, use is expected to reach 816 million bushels, up nearly 20 percent from the 1993/94 forecast.

In lieu of new "green" legislation, the demand for starch, primarily cornstarch, is expected to grow in tandem with the overall U.S. economy. One use of cornstarch is in the production of citric acid, the main acidifier (by volume) used by the food and pharmaceutical industries. Current domestic consumption of citric acid is estimated at 360 million pounds annually, which requires approximately 16 to 18 million bushels of corn.

About 15 percent of the plasticizers produced in the United States is derived from plant matter, mostly vegetable oils, and the market is growing 3 to 5 percent a year. The market for epoxidized soybean oil may expand tremendously if it can be incorporated into paints and coatings to replace volatile solvents. The CAAA requires paint manufacturers to reduce volatile organic compounds in their formulations.

New regulations issued by the U.S. Environmental Protection Agency in the last few years make diesel fuel subject to sulfur standards and engine-emission requirements, which may open niche markets for biodiesel. Beginning October 1, 1993, diesel fuel for on-highway uses must be low in sulfur. High-sulfur diesel fuel may still be sold, but it must be dyed blue and can only be used in off-road applications. The recent change to low-sulfur diesel fuel for on-road vehicles has raised questions about the lubricating properties of the reformulated fuel. An upcoming field test will examine the lubricity of biodiesel/petroleum diesel blends.

Inflation-adjusted lumber prices are volatile but are trending upward over the long term, reflecting lower public timber harvests and other supply and demand factors. In response, engineered wood products and wood substitutes are becoming more attractive. The market for laminated wood I-joists and beams, laminated veneer lumber, and glue-laminated (glulam) materials is expected to double from 1992 to 1997. Steel framing is making some inroads into traditional lumber use, but wood remains the predominant building material for residential construction in the United States.

In mid-April 1994, Taxol, previously approved for the treatment of ovarian cancer, was also approved by the U.S. Food and Drug Administration (FDA) to treat breast cancer. The demand for Taxol is expected to increase. To date, deriving paclitaxel (the bulk drug containing Taxol) from the bark of the Pacific yew tree is the only FDA-approved process. However, recent advances in semi-synthetic production methods, particularly needle- and twig-derived paclitaxel, are expected to replace bark harvest. Such a process is pending FDA approval.

A study found that the energetic and economic feasibility of converting beef tallow to biodiesel was generally positive. The cost of producing tallow-based biodiesel ranged from 92 cents to $1.67 per gallon, depending on the price of the tallow feedstock, the price received for the glycerine coproduct, and the type and size of the trans-esterification unit. With diesel prices averaging 71.2 cents during the last couple of years, biodiesel must find a market niche to compete, possibly as blends with petroleum-based diesel to meet Clean Air Act requirements.

New coproducts from ethanol production offer potential for improving its profitability. However, technical challenges must be overcome before this potential can be realized. Research is underway to find new specialty chemical or foodgrade products that can be economically produced. These products will probably serve high-value niche markets.

U.S. and European Activities Promote Biobased Industrial Products

The search for new industrial uses of agricultural materials is occurring in many countries. In the United States, projects funded by USDA's Alternative Agricultural Research and Commercialization Center and Cooperative State Research Service, Office of Agricultural Materials have begun to yield results. USDA's Agricultural Research Service continues to expand its technology transfer activities. Projects at the U.S. Department of Energy focus on developing high-volume chemicals from biomass. The European Union and its member countries are investing in research and demonstration projects, like the Biorefinery Concept in Denmark.

Updates: USDA's AARC Center

In fiscal year 1994, USDA's Alternative Agricultural Research and Commercialization (AARC) Center received $9 million for new industrial-uses projects. The Center issued a competitive request for proposals in June 1993 for fiscal 1994 and received 160 proposals. Of these, the AARC Board chose 47 to develop into full proposals. Twenty projects were selected. Half of these have been funded, with negotiations continuing on the rest. Some of the projects funded thus far include: stress-skin construction panels made from compressed wheat straw by Agriboard Industries L.C. (Fairfield, IA); oil-absorbent booms and socks, which contain natural bacteria to bioremediate the oil, produced by Environmental Remediation Technologies (Clinton, MS); and a new biological fungicide, which uses ground bark or crop and grass residues as the carrier, manufactured by Innovative Biosystems, Inc., (Moscow, ID). Criteria used in awarding funds include:

- economic viability,
- private financial participation,
- potential market size,
- potential for job creation and rural development (especially in economically distressed rural areas),
- State or local government participation,
- likelihood of reducing federal commodity support outlays,
- likely impact on the environment,
- lack of adequate private funding,
- viability without continued assistance,
- and eventual ability to repay the AARC revolving fund.

The projects funded in fiscal 1993 have begun to yield results. Gridcore Systems International (Carlsbad, CA) is selling its composite material made from kenaf, wood fibers, and/or recycled corrugated containers to "The Gap" clothing stores. Sales of Ogallala Down comforters and pillows, made with milkweed floss and goose and duck down, by Natural Fibers Corporation (Ogallala, NE) are up and the company is nearing the break-even point.

Five major European automobile manufacturers are now recommending the rapeseed-oil lubricants made by International Lubricants, Inc., (Seattle, WA) to their customers. The company's sales have grown 70 percent per year for the last 4 years. CCT Corporation (Carlsbad, CA) is awaiting approval from the U.S. Environmental Protection Agency (EPA) so it can commercially manufacture its granular matrix that will contain a biopesticide for use on corn. Hobbs Bonded Fibers (Mexia, TX) is now selling oil-absorbent pads made from low-grade wool on a commercial scale. Leahey Wolf Company (Franklin Park, IL) has a biodegradable, concrete-form release agent made from industrial rapeseed oil on the market.

Phenix Composites (Mankato, MN) has started commercial production and made initial sales of its "Environ" composite construction panels that are made from recycled newspaper, soybean meal, and binders. Aquinas Technologies (St. Louis, MO) has introduced a summertime windshield washer fluid made with ethanol and will soon add a winter product.

CSRS's Office of Agricultural Materials Consolidates Program in Fiscal 1994

In fiscal 1994, USDA's Cooperative State Research Service, Office of Agricultural Materials received $3.2 million to fund projects developing industrial uses of agricultural crops and materials. Some of the projects include development of: hesperaloe as a new "hard" fiber, industrial oilseeds such as crambe and lesquerella, hypoallergenic latex and other products from guayule, and industrial products from wheat. The joint USDA-U.S. Department of Defense (DOD) program received $4.7 million in fiscal 1993 and $2.5 million is anticipated in fiscal 1994. This program is targeting the development of biodiesel and other environmentally friendly fuels and lubricants; biodegradable, oil-selective adsorbents; nylons and epoxies from vegetable oils; natural biocides; and low volatile-organic-compound (VOC) paints and coatings.

Lesquerella made its public debut at a field day in Maricopa, AZ, on April 19, 1994. At the Field Day, research presentations ranged from plant breeding and germplasm development, production practices, and successful feeding trials of the meal, to product research and development. Lesquerella oil is similar to castor oil, except that its

hydroxy fatty acid has two more carbon atoms than castor, which may make lesquerella oil superior to castor oil in some applications, particularly in cosmetics. Lesquerella research and commercialization is being supported by the Office of Agricultural Materials, using DOD funds, and by the AARC Center. In the 1994/95 growing season, selected farmers are expected to grow test fields of lesquerella.

Hypoallergenic surgical gloves and other rubber products can potentially be manufactured from guayule latex (see the December 1993 issue of this report for more information). This is good news for people who are allergic to the proteins in Hevea rubber products. Research has been accepted for publication that demonstrates antibodies against proteins in Hevea rubber products do not recognize guayule latex proteins. Related research is under way to prepare sufficient guayule latex for material fabrication and testing by commercial firms. The long-term guayule rubber program administered by the Office of Agricultural Materials is achieving some of its major goals by testing prototype tires on U.S. Army trucks in Yuma, AZ, and on Navy aircraft at Patuxent, MD, this summer.

In 1994/95, yield trials will be conducted in Arizona, Texas, Oregon, and Puerto Rico on vernonia, a plant with epoxy-containing oil. The variety being tested is only six generations from a natural hybrid, which will flower in the short days of temperate North America. The epoxy oil may be used to make low-VOC paints and specialized plastics.

Agricultural Research Service's Technology Transfer Accelerates

In fiscal 1993, USDA's Agricultural Research Service (ARS) more than doubled the number of joint agreements signed with industry to develop ARS technology. The number of Cooperative Research and Development Agreements (CRADA's) in 1993 reached 59, compared to 37 a year earlier. In fiscal 1993, ARS issued 25 licenses to private companies to develop ARS-patented discoveries. Overall, ARS accounts for about 80 percent of USDA's patents. Approximately two-fifths of ARS licenses are for industrial uses. For example, ARS licensed technology that is used to manufacture printing inks from 100-percent vegetable oil to Franks Research Laboratory (Oklahoma City, OK).

When technology is transferred, it helps rural communities grow and creates jobs. For example, Central Illinois Manufacturing Company (Bement, IL) increased its employment to 120 and sales to $10 million by selling fuel filters that use a cornstarch-based adsorbent developed by ARS. Canadian Harvest USA built a milling plant in Cambridge, MN, and hired 60 people to work there. The company makes low-calorie, high-fiber baking products with ingredients isolated from oat hulls, using ARS technology (see the special article on ethanol coproducts).

In fiscal 1994, ARS received $79.5 million for research and development of new uses for agricultural commodities. Of this, $45.3 million is allocated to new, nonfood uses and $34.2 million to new foods and processing systems. Examples of ARS's nonfood research include programs on improving microorganisms for bioconversion, such as for ethanol and biomolecular fermentation; utilizing agricultural products in plastics, fibers, and membranes; and identifying and extracting biologically active chemicals such as enzymes, pharmaceuticals, and antibiotics.

Past ARS research efforts have resulted in patents on the use of cross-linked starch in biodegradable plastics, colored soy-ink, super-slurper, soy-oil-based nylons, guayule-based rubber, wrinkle-free cotton, penicillin, and many others. Recent research efforts have resulted in the major new dietary product, Oattrim, which is modified oatstarch and soluble fibers. Other discoveries include new, heat-sensitive cotton for use in military and sporting goods. Genetic engineering efforts are producing improved yeast for ethanol fermentation, ways to ferment orange peels to ethanol, and new biopolymers from amino acids and fermented sugars. Soyoil research has resulted in new processes for modifying waste fatty acids into industrial-processing additives and as components in cosmetics, detergents, plastics, and coatings. Research underway on corn and wheat proteins is resulting in new ways to chemically and enzymatically modify their reactive properties to open up new uses as plastics, membranes, and oxygen barriers.

Department of Energy Expands Its Renewable Fuel and Chemical Programs

The Biological and Chemical Technologies Research Program in the U.S. Department of Energy's (DOE) Office of Industrial Technologies has recently concluded a technical and market analysis of the current top-50 commodity chemicals produced in the United States. This analysis is being used to evaluate additional research and development opportunities using biomass feedstocks for the production of high-volume chemicals. The study compiled information on various economic, environmental, and energy characteristics of the chemicals, for example, capital intensity, market share trends, and energy consumption for processing and feedstocks.

Nineteen chemicals were identified as possible targets for replacement by biomass feedstocks. Several are among the top-50 U.S. chemical products. Gasification and pyrolysis were targeted as likely process routes for production. A copy of *A Chemicals and Petroleum Refinery Initiative to Impact the Top 50 Commodity Chemicals Produced in the United States* is available through the Program Manager, David Boron, (202) 586-0080.

The Alternative Feedstocks Program, also administered by DOE's Office of Industrial Technologies, has recently

added a project to develop life-cycle-analysis (LCA) decision tools to help direct research and development priorities and options for chemicals from renewable resources. This project is a cooperative effort between EPA and DOE's Idaho National Engineering Laboratory. The goal is to integrate the LCA module with production-facility economic software developed by the National Renewable Energy Laboratory to incorporate market realities into setting priorities for technology development.

Funding for research and development of chemicals from renewable resources and related chemical processing technologies within DOE's Alternative Feedstocks and Biological Technologies Research Program is being targeted for a 20- to 30-percent increase in fiscal 1995 over the $7.86 million received in fiscal 1994. The additional funds will support pilot plant activities and further process development, which will be conducted in partnership with industry.

DOE, USDA, DOD, and other federal agencies are cosponsoring the Biobased Products EXPO '94 in December 1994. The EXPO is an opportunity for technology developers, potential investors, and customers to see what is new in industrial uses of agricultural and forestry materials. EXPO '92 attracted over 450 participants and more than 100 exhibits of science, technology, and new products. For information on attending or exhibiting at the EXPO, see Upcoming Events at the end of this article. The proposed deadline for exhibitor applications is the end of August.

Denmark's Biorefinery Concept

The most concerted efforts outside the United States to find new industrial uses of agricultural materials are in the European Union (EU). Indeed, the approaches in the EU and its member countries to developing new uses differ from the U.S. approach, and in general receive more public-sector support.

For example, agricultural and industry interests in Denmark entered into an arrangement in 1990 with five other European countries, plus other parties, to develop new uses for agricultural materials. The group will complete the first phase of its effort by the end of this year. Specifically, the group is developing and testing technologies that treat and fractionate key crops to isolate new products, especially for nonfood uses. The total budget for this effort is $9 million. Other European nations and the EU also have programs to develop new industrial uses of agricultural materials.

The Danish-led group is focusing on wheat and oilseeds, primarily rapeseed. The overall purpose is to break these crops down into all relevant components and examine their market potential, given today's changing industry and consumer needs. The effort represents a comprehensive, vertically integrated approach--harvesting, transportation, storage, processing, and market development. Called the Biorefinery Concept (figure 1), it encompasses farmers as well as marketers of the final products--food, feed, energy, and other industrial uses. Major players include the Green Center, Novo-Nordisk, Westfalia Separator, and the Institute of Agricultural Economics, among others (figure 2).

In the pilot plant, different separation technologies and product lines for all parts of the plant were examined. The group readily admits, however, that its product-development component is the weakest link. Industry partners are interested in improving the efficiency of current product lines. Upgrading the value of byproducts or finding markets for current waste streams is of primary interest to farmers and farm organizations involved in the project. In the next phase, a full-scale demonstration project is planned, which is the last step before establishing commercial plants.

Initial economic analysis suggests that the Biorefinery Concept should be feasible for wheat. The products are broken out as Bioraf I, which includes products from whole wheat, and Bioraf II, which includes products from wheat straw (figure 3).

European Efforts Set to Expand

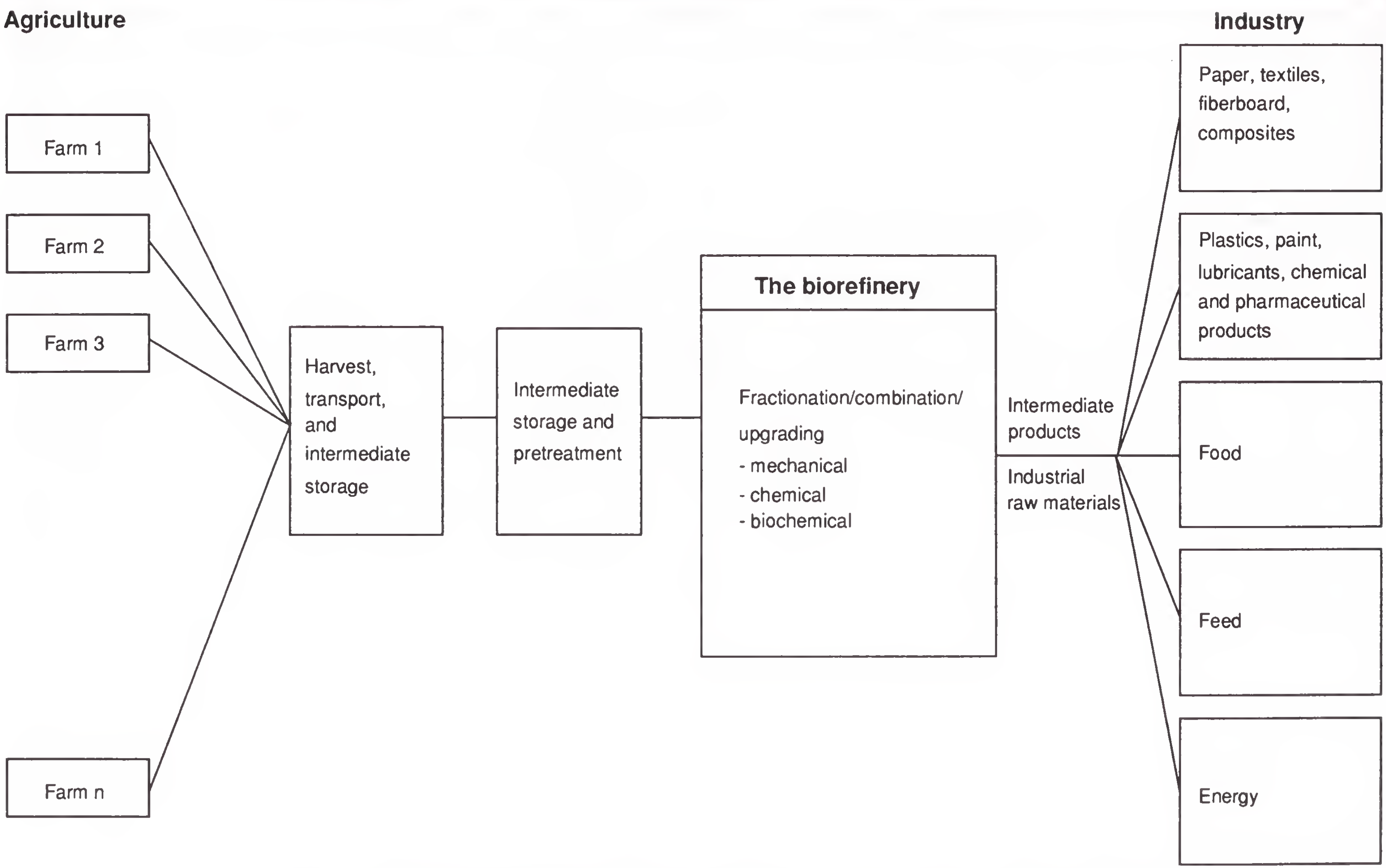
In general, Europeans are ahead of the United States in coordinating their research, development, and demonstration activities in exploring opportunities for new industrial uses for agricultural materials. However, interaction with new startup entrepreneurs is minimal. The Europeans do not have a program like USDA's AARC Center that emphasizes market pull instead of technology push. Some Europeans would like to explore a similar organization but are not sure their politicians are ready for it. However, the Europeans do plan to expand aggressively into the demonstration phase of these programs--not only for wheat and rapeseed, but also for alternative crops like kenaf, elephant grass, hemp, and rapeseed-based biodiesel.

In the fourth framework program, just getting underway, the EU is planning to spend the equivalent of $117 million over 4 years in the nonfood, new-uses arena, which does not include support from member countries or industry. When this support is included, the total will be two to three times the EU contribution.

The comprehensive nature of the EU's program is stimulating the diversification of agriculture. Production, processing, end use, demonstration, and information transfer are all handled under one umbrella framework. U.S. government and industry are working to find ways to share information with the Europeans on how best to convert renewable materials into useful products. Both sides of the Atlantic are interested in reducing the price-depressing effects of overproduction, and when each side succeeds, both benefit. A possible transatlantic conference

Figure 1

The Biorefinery Concept



Source: The Whole Crop Biorefinery Project, Mid-Term Assessment, Morten Gylling, Bioraf Denmark Foundation, Aakirkeby, Denmark, October 1993.

Figure 2

Activities and Participants of the European Whole-Crop Biorefinery Project

MODEL OF FULL-SCALE BIOREFINERY SYSTEM

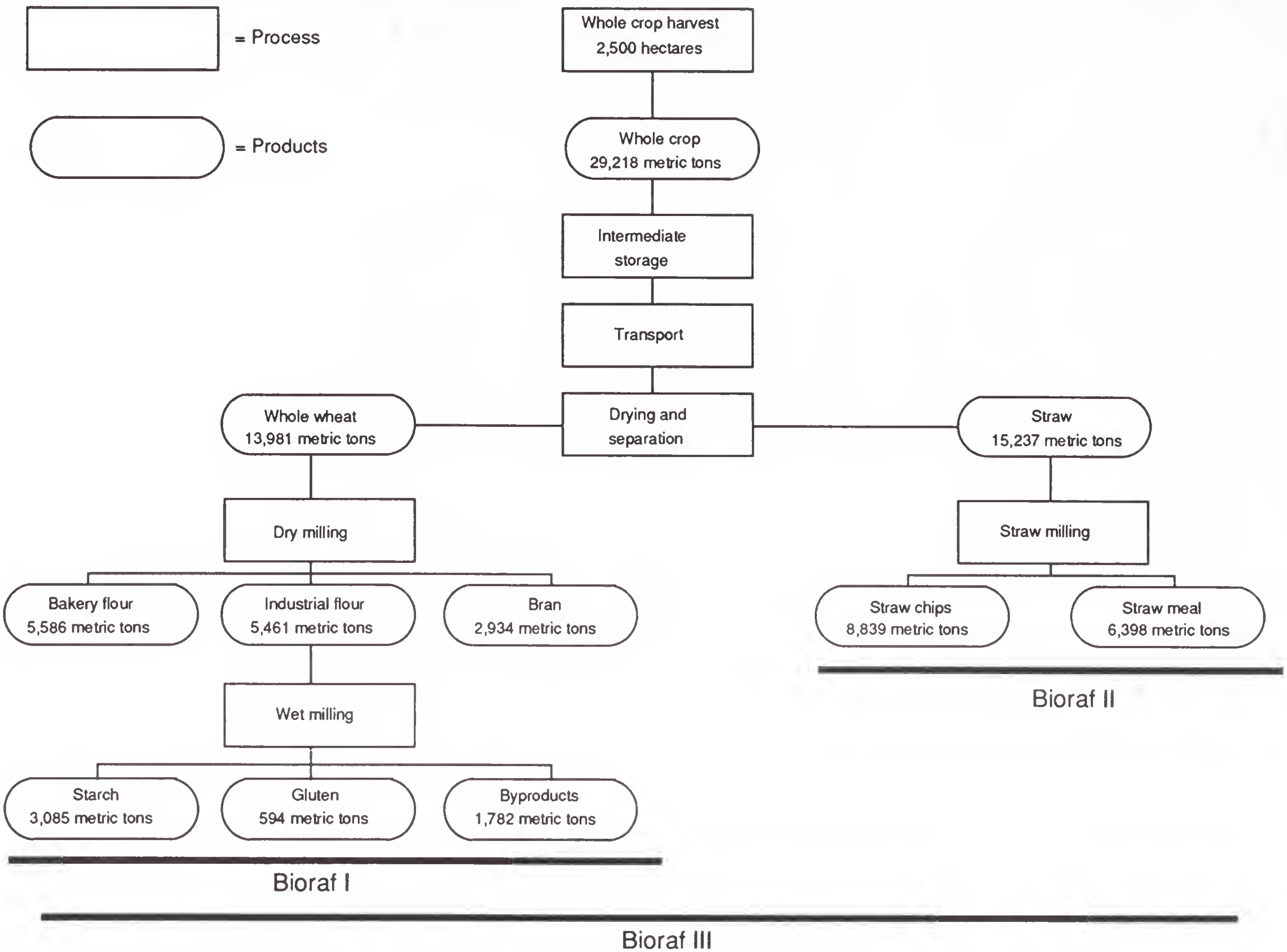
Technology, mass balances, cost relations

Elements in the biorefinery production system	Activity	Participants: Partners and associates	Participants: Subcontractors
Plant breeding and selection	1. Selection and development of suitable plant species	Green Center, Denmark Institute of Crop Science, France Braunschweig, Germany	Research Service for Soil and Plant Sciences, Denmark
Cultivation, harvesting, and transport	—	—	—
Intermediate storage	2. Intermediate storage, separation and drying of whole crops	Biotechnological Institute, Denmark Teagasc, Ireland	Brdr. Westrup, Denmark
Drying, dry separation	—	—	—
Fractionation	3. Integrated upgrading of wheat and barley to starch and feed ingredients	United Milling Systems, Denmark	Vioryl, Greece
	4. Production and analysis of fiber fractions from straw and biomass	United Milling Systems, Denmark National Technical University of Athens, Greece	Brdr. Westrup, Denmark
	5. Enzymatic extraction of oil, protein, and starch Integration of fractionation techiques	Novo-Nordisk, Denmark United Milling Systems, Denmark Westfalia Separator, Germany	Institute of Chemistry and the Royal Veterinarian and Agricultural University, Denmark
Use of outlets, marketing	Product tests and market surveys included in above activities	—	—
Data registration, integration, economic feasibility	6. Systems analysis and economic assessment of the Integrated Biorefinery System	Institute of Agricultural Economics, Denmark Silsoe Research Institute, United Kingdom	—

Source: The Whole Crop Biorefinery Project, Mid-Term Assessment, Morten Gylling, Bioraf Denmark Foundation, Aakirkeby, Denmark, October 1993.

Figure 3

Bioraf Model of Whole Crop Wheat 1/



1/ All amounts are on a dry-matter basis.

Source: The Whole Crop Biorefinery Project, Mid-Term Assessment, Morten Gylling, Bioraf Denmark Foundation, Aakirkeby, Denmark, October 1993.

on value-added industrial uses in the spring of 1995 is under consideration. [Greg Gajewski (202) 219-0085 and Paul O'Connell (202) 401-4860]

Upcoming Events

July 11-13, 1994, SERBEP Wood Recycling Conference and Exhibition: Opportunities for Waste Generators and Solid Waste Facilities in the Southeast, Charlottesville, VA, sponsored by the Southeastern Regional Biomass Energy Program (SERBEP). For information, contact C. T. Donovan Associates, Inc., P.O. Box 5665, Burlington, VT, 05402, (802) 658-9385.

July 15, 1994, SERBEP Biogas Recovery and Use Workshop at the Northside Wastewater Treatment Plant, Durham, NC, sponsored by the Southeastern Biomass Energy Program. For information, contact John Wander, Wander Associates, 1933 Rockingham St., McLean, VA, 22101, (703) 533-8333.

July 15, 1994, Alternative Feedstocks Program, Rockville, MD, sponsored by the U.S. Department of Energy and its national laboratories. For information, contact Joan Ross, National Renewable Energy Laboratory, Golden, CO, (303) 231-1412, fax (303) 231-1905.

July 24-29, 1994, Annual Meeting of the Council on Forest Engineering, Portland and Corvallis, OR. For information, contact Loren Kellog, Department of Forest Engineering, 213 Peavy Hall, Oregon State University, Corvallis, OR, 97331-5706, (503) 737-2836.

September 26-30, 1994, First North American Conference and Exhibition: Emerging Clean Air Technologies and Business Opportunities, Toronto, Ontario, sponsored by Environment Canada. For information, contact Raymond Klicius, Environment Canada, Technology Development Branch, Ottawa, Ontario, K1A OH3, (819) 953-8717.

September 26-30, 1994, Ninth International Conference on Jojoba and Its Uses and the Association for the Advancement of Industrial Crops Annual Meeting, Catamarca, Argentina, sponsored by the Latin American Jojoba Association and the Association for the Advancement of Industrial Crops. For information, contact James Brown, International Flora Technologies, Ltd., 2295 S. Coconino Drive, Apache Junction, AZ, 85220, (602) 983-7909.

October 1994, Eighth European Conference on Biomass for Energy. For information, contact Dr. G. Grassi, Commission of the European Communities, DG XII, Brussels, Belgium, fax 32-2-296-3024.

October 2-6, 1994, Bioenergy '94, Reno, NV, sponsored by the Western Regional Biomass Energy Program (WRBEP). For information, contact David Swanson (WRBEP program manager), c/o Western Area Power Administration, A7100, P.O. Box 3402, Golden, CO, 80401, (303) 275-1706.

October 3-7, 1994, BioResource Business Opportunities: Profit From a Sustainable Future (BioResources '94 conference), Bangalore, India, sponsored by Biomass Users Network, International Energy Initiative, Stockholm Environment Institute, and the Commonwealth Science Council. For information, contact LaRocco Associates, 2 Erie Street, Montclair, NJ, 07042, (201) 509-7900.

October 10-12, 1994, Animal Coproducts '94, Kansas City, MO, sponsored by USDA's Cooperative State Research Service, Kansas Department of Agriculture, businesses, and other organizations. For information, contact Raymond Burns, Kansas Department of Agriculture, 901 S. Kansas Ave., Topeka, KS, 66612-1282, (913) 296-1907.

December 5-7, 1994, Biobased Products EXPO '94, trade show and conference, Kansas City, MO, sponsored by the New Uses Council, U.S. Department of Energy, U.S. Department of Agriculture, and the U.S. Department of Defense. For information, contact Barbara Detwiler, Science Applications International Corporation, 1710 Goodridge Drive, MS-2-2-5, McLean, VA, 22102, (703) 734-4081, fax 703-356-4056.

Strong U.S. Economic Growth Ahead Provides Solid Support for Agriculturally Based Industrial Products

Strong growth is occurring in 1994. Inflation is expected to be low. The Federal Reserve Board put upward pressure on interest rates, but most interest-sensitive sectors, including housing and furniture that rely on forest products, should be profitable and grow during 1994. Petroleum prices are likely to rise this year, giving some support for agriculturally based fuels and lubricants.

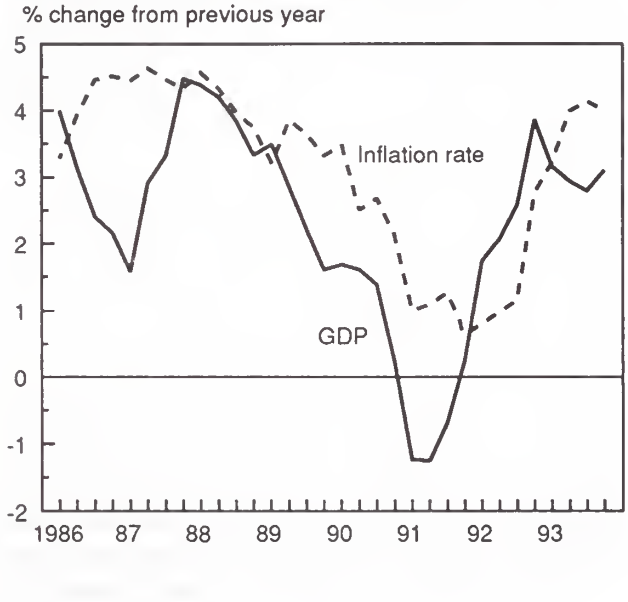
The consensus of private forecasters is that the U.S. Gross Domestic Product (GDP) will grow 3.6 percent in 1994 (figure 4). Consumer price inflation is expected to be 2.8 percent. The Federal Reserve Board (Fed) put upward pressure on short-term interest rates to restrain future growth in demand that would spark higher inflation. Banks reacted with the first increases in the prime rate in 6 years. Long-term rates rose and then fell, but are still above early 1994 levels.

Economic Growth Is Strong Across Sectors

In the third quarter of 1993, growth was almost 3 percent and would have likely been 3.5 to 4 percent if not for rain-related losses in the Midwest. Growth, however, was very strong in the fourth quarter. Oil prices fell and short- and long-term interest rates were at or near record lows. Moreover, bank, consumer, small business, and corporate balance sheets were extraordinarily healthy. Banks were ready and able to lend. The booming stock market made the cost of issuing new equity very inexpensive, which, together with strong corporate profits, boosted purchases of new factories and equipment.

Figure 4

Real GDP Growth Accelerates, but Inflation Is Forecast To Rise Slightly



Individuals were willing and able to borrow for new and previously owned houses, as well as cars to replace their aged vehicles. People also needed to furnish their newly purchased houses. As a result, the 7.0-percent growth in furniture shipments during fourth-quarter 1993 set a 10-year record. Consumer spending on durable goods, housing, and cars and business spending on equipment all grew at annualized rates of almost 20 percent in the fourth quarter. The real trade deficit even narrowed, an historically unprecedented happening this far along in a recovery.

GDP growth in first-quarter 1994 was 3.0 percent, higher than expected by most private forecasters. Growth was led by spending on business equipment and consumer durables, which grew 16.1 and 10.2 percent. Residential investment posted a 7.6-percent gain. Except for spending on business structures, which fell 20.1 percent, every major interest-sensitive component of GDP rose faster than aggregate GDP. The other large drags on growth were a 3.6-percent decline in government spending and a 14.7-percent increase in imports.

Consumers and businesses are borrowing and spending more compared to a year ago. Financial intermediaries, such as banks, have increased lending and underwriting stock issues. That is why the strength of fourth-quarter 1993 did not fizzle in the first quarter of this year, despite a very high initial growth rate, a major earthquake, and bad weather.

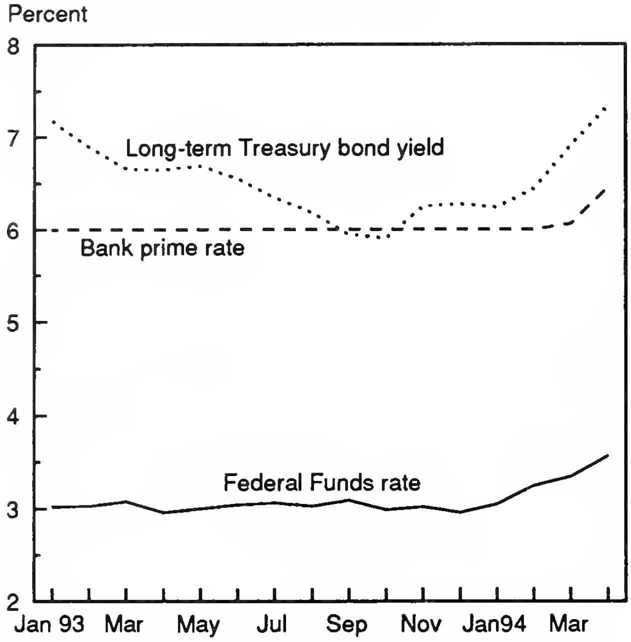
Interest Rates Begin To Move Up

The low interest rates engineered by the Fed beginning over 5 years ago allowed solid improvement in the balance sheets of financial institutions, corporations, small businesses, farmers, and consumers. For example, home mortgage refinancing gave many consumers a substantial boost in spending power (after out-of-pocket expenses).

In early 1994, the Fed decided that since the economy was on a solid recovery path, it was time to institute a neutral monetary policy to prevent a resurgence of inflation. As a result, in February, March, and April, the Federal Funds rate (the rate at which banks borrow from one another) was raised (figure 5). The prime borrowing rate at the end

Figure 5

Fed Lifts Federal Funds Rate



of April was 6.75 percent, up from 6.0 percent in early 1994.

Some analysts expect the Fed to push up interest rates again later this year. Because of these interest rate hikes, most analysts expect GDP growth to be slower than it would have been otherwise in the last quarter of 1994. It is likely that consumer durables and business investment will still grow at substantial rates (up to and exceeding 10 percent) for 1994 as a whole. Home sales are likely to fluctuate more from quarter to quarter than other interest-sensitive sectors, but will wind up higher in 1994 than in 1993--up around 8 to 10 percent.

Overall GDP growth for 1994 of 3.6 percent will give a lift to many agricultural processors selling to the industrial sector. Unemployment is expected to average 6.4 percent, down from March's 6.5 percent. Some analysts had called for a very strong first-half of 1994, followed by GDP growth below 2 percent in the last half of the year. However, the moderate results of the first quarter lower the probability of such a sharp slowdown, even in the presence of additional increases in the Federal Funds rate.

Oil Prices To Move Up

Energy is an important input in most industrial processes. In general, increases in petroleum prices will stimulate demand for agricultural materials used for lubricants, feedstocks, or energy sources. For the rest of 1994, most analysts expect higher petroleum prices. However, the increases will be from very low levels. A late-November meeting of the Organization of Petroleum Exporting Countries (OPEC) failed to come up with an operational quota. Crude oil prices on the New York Mercantile Exchange (NYMEX) fell below $14 per barrel in the first quarter of 1994.

Large producers were more in accord at OPEC's spring meeting. A forecast by the U.S. Department of Energy's Energy Information Administration (EIA) calls for the cost of imported crude to average $15 per barrel for the first half of 1994, rising to $16 in the last quarter, and averaging $15.39 for the year. Private analysts, having more current information, now expect crude prices to rise about $2 per barrel above the current NYMEX spot price of $18 by the end of 1994. Long-term projections by EIA have oil prices rising to $20 per barrel in 1987 dollars by the year 2005.

Expected Effects of Growth in Buildings, Housing, and Furniture Cut Across Economy in 1994

The consensus has industrial production growing 4 percent in 1994. As the recovery continues, construction and related activity is expected to grow even more strongly. Specifically, commercial building, residential housing, and the furniture sector are forecast to grow rapidly. These sectors are large users of agricultural materials, particularly forest products.

An ERS sector-level simulation model was used to estimate the changes in these sectors in 1994 and the resulting impacts on the rest of the domestic economy. The results of expected changes in gross private domestic investment in commercial buildings, residential housing, and furniture consumption are measured in terms of total output and GDP. GDP represents the value added in production: it is the value of total industrial output less the cost of intermediate inputs, which are the products of one industry used by another. Total output and GDP for the economy are the sum of each industry's total output and GDP.

Furniture production will increase 8 percent or $17.2 billion (in constant 1987 dollars) in 1994 to meet new consumption demands; investment in buildings will increase 7.2 percent or $8 billion; and investment in residential structures will increase 9.7 percent or $20 billion (table 1).

The bottom half of table 1 indicates the economic activity resulting from this level of investment and consumption. These changes alone will generate an increase in the economy's total output of over $222.5 billion in current dollars and almost $98 billion of GDP. As would be expected, construction GDP increased considerably, over $7.2 billion. The first category, farm and agricultural services, also shows large increases in both output and GDP. Horticultural services, forestry, and landscaping are included in this category. These industries, with their strong links to housing, have long been valuable markets for nonfood agricultural commodities. From nursery stock to bedding plants, this activity stimulates demand for

established products. It also encourages demand for new products, ranging from kenaf seeding mats, included in the farm and agricultural services category, to concrete-release agents and biolubricants used in construction and related equipment, which are products of the corn and oil mills category.

Total GDP in 1994 related to the increase in investment and consumption is $1.25 trillion, 18 percent of the $6.77 trillion forecast for 1994 U.S. GDP. The manufacturing sectors--furniture, lumber and wood, plastics and rubber, petroleum refining, corn and oil mills, textiles, and leather--benefited the most. Service sectors and mining also generate high levels of output and GDP. Within the mining sectors are those quarrying activities associated with cement mixing and gravel, so this link is not surprising.

The simulation model used in this analysis has 1982 as its base year, reflecting a cost structure and sectoral composition of a decade ago. These estimates may not capture the full extent of more recent uses of agricultural materials. However, many agricultural materials have replaced other materials in existing activities, rather than in entirely new products. Therefore, these results suggest the size of the potential markets in which agricultural materials may be able to penetrate with new and improved materials. [David Torgerson and William Edmondson (202) 219-0782]

Table 1--1994 economic activity related to expected totals and increases in furniture consumption, investment in commercial buildings, and investment in residential housing

Sector	Consumption and investment	
	Total 1994	Change 1993-94
	Billion 1987 dollars	
Furniture	234	17.2
Buildings	118	8.0
Housing	227	20.0

Sector	Economic activity			
	Total 1994		Change 1993-94	
	Output	GDP	Output	GDP
	Million 1994 dollars			
Farm and agricultural services	127,400	47,598	9,957	3,713
Construction	181,089	92,097	14,243	7,225
Furniture	43,457	19,758	3,381	1,527
Lumber and wood	73,466	23,885	5,941	1,942
Plastics and rubber	99,754	36,884	7,699	2,837
Petroleum refining	78,680	11,403	6,168	895
Corn and oil mills	39,095	6,613	3,097	506
Textiles	64,318	12,771	4,807	960
Leather	15,757	3,195	1,296	263
Other manufacturing	1,083,543	379,329	84,101	29,357
Services and mining	837,108	481,432	64,791	37,395
Trade and transportation	221,085	141,848	17,065	10,947
Total	2,864,753	1,256,814	222,548	97,566

Ethanol and Citric Acid Increase the Use of Corn

Continued implementation of the Clean Air Act Amendments of 1990 is expected to put upward pressure on the industrial demand for corn during the remainder of the 1993/94 marketing year and 1994/95. The final rule from the U.S. Environmental Protection Agency on ethanol's role in the reformulated gasoline program is due out this month. In lieu of new "green" legislation, the demand for starch, primarily cornstarch, is expected to grow in tandem with the overall U.S. economy. One use of cornstarch is in the production of citric acid, the main acidulant used by the food and pharmaceutical industries.

Use of corn to produce industrial starch and fuel alcohol during 1990/91 through 1994/95 is expected to rise at an average rate of 10 percent per year (table 2). Because of strong economic growth and continued implementation of the Clean Air Act Amendments of 1990 (CAAA), corn use is forecast at 683 million bushels in 1993/94, almost a 9-percent increase from 1992/93. In 1994/95, use is expected to reach 816 million bushels, up nearly 20 percent from the 1993/94 forecast. Again, continued increases in fuel alcohol usage as a result of the CAAA is the main reason for the rise.

Fuel Alcohol Use Up, but Future Increases Are Uncertain

After lower-than-expected demand for oxygenates generated by the CAAA's carbon monoxide provisions during the winter of 1992/93, the winter oxygenate program went smoothly in 1993/94. From September 1993 though February 1994, the amount of corn used to produce fuel alcohol was up 9 percent from the same period a year earlier. The additional alcohol was used to meet requirements of the CAAA, which were in force for 39 metropolitan areas and counties that failed to meet carbon-monoxide air-quality standards. Under the CAAA's winter oxygenate provisions, gasoline sold during at least the 4 winter months must contain 2.7 percent oxygen by weight.

In addition to strong domestic demand from the winter oxygenate program, export demand developed from Brazil, which put upward pressure on ethanol prices. From September 1993 through March 1994, 44 million gallons of ethyl alcohol were shipped to Brazil. Even though fuel alcohol production per day slowed in March from the February level, production was still above a year earlier. Since the winter oxygenate program ends in February in most metropolitan areas, exports probably took the extra supply, because stocks were lower.

Table 2--Industrial uses of corn, 1990/91-1994/95

Marketing year 1/	Starch: Food uses	Starch: Industrial uses	Starch: Total 2/	Fuel alcohol	Total industrial use
	Million bushels				
1990/91	35	197	232	349	546
1991/92	36	202	237	398	600
1992/93	36	202	238	426	628
1993/94 3/	37	208	245	475	683
1994/95 4/	38	213	250	603	816

1/ Marketing year begins September 1. 2/ Total starch use equals food use plus industrial use, with 85 percent going to industry and 15 percent to food uses. 3/ Forecast. 4/ Projected.

The second stage of the CAAA, the reformulated gasoline (RFG) program, is to be implemented in 1995. RFG requires oxygenates to be used in the nine areas with the worst concentrations of ground-level ozone. Another 86 areas may decide to be included. Because splash-blending ethanol with gasoline may increase evaporative volatile-organic-compound (VOC) emissions and methyl tertiary butyl ether (MTBE)--a fossil-fuel distillate--does not, ethanol-blended RFG will require lower evaporative emissions from the gasoline component than MTBE-blended RFG. Depending on the cost of decreasing evaporative emissions in gasoline, this could drive up the relative price of ethanol-RFG blends, and for all practical purposes, price fuel ethanol out of the ozone nonattainment market. One solution is to use ethyl tertiary butyl ether (ETBE), which is derived from ethanol. ETBE-blended RFG does not increase VOC emissions, but the question is whether it will compete with MTBE-blended RFG. In December 1993, the U.S. Environmental Protection Agency (EPA) issued a proposed rule that 30 percent of the "oxygenate" in reformulated fuels come from renewable resources, which would be primarily ethanol. A final EPA ruling on the matter is expected this month.

Inclusion of ethanol in the RFG program will significantly boost ethanol demand. If RFG is enacted as proposed, corn demand for fuel alcohol in 1994/95 is expected to increase 27 percent from the 1993/94 forecast of 475 million bushels. Some of this additional alcohol will also be needed to meet increased demand created by the CAAA's carbon monoxide provisions.

Current ethanol capacity is probably near the 85,000 barrels per day produced in November and December 1993. If so, capacity would be 31 million barrels or 1.3 billion gallons of fuel alcohol per year. With 95 percent of production from corn, 495 million bushels would be

needed, which is below the 1994/95 projection of 603 million bushels. However, as discussed in the December issue of this report, producers are expected to meet demand by building additional capacity or by bringing some unused capacity back into production.

Starch Use Expected To Track U.S. Economic Growth

In lieu of new "green" legislation, the demand for starch, primarily cornstarch, is expected to grow with the overall U.S. economy. Starch production in the first half of 1993/94 used 2 percent more corn than in the same period of 1992/93. Since cornstarch production is usually stronger during the second half of the year, a 3-percent increase in cornstarch use is forecast for 1993/94. Much of the starch is used in paper products and building materials, such as wallboard. As the economy grows and construction increases, more shipping boxes and other types of paper are needed, thus boosting the demand for cornstarch and ultimately corn. A 2-percent rise in demand is expected in 1994/95.

More Citric Acid Is Produced From Biobased Sources

One use of cornstarch is in the production of citric acid, the main acidulant (by volume) used by the food and pharmaceutical industries. An acidulant is acid in taste and, in the food industry, it functions mostly as a flavor enhancer. Acidulants also retard the growth of bacteria and other organisms that cause spoilage, thus acting as a preservative. Citric acid accounts for an estimated two-thirds of the U.S. acidulants market. Acidulants used in foods and beverages consume an estimated 65 percent of total demand, with beverages requiring the bulk of the total.

In the United States, citric acid has been produced from both petroleum and biobased processes. Recently, production has been shifting more toward biobased routes, which depend on a special microbial strain of *Aspergillus niger* to ferment crude sugars or cornstarch in the presence of oxygen. The sugar feedstock can be derived from any starch-rich crop, including wheat, barley, and rice. There are currently three fermentation processes used to produce citric acid: solid state, liquid state, and submerged-culture fermentation. The solid-state fermentation technology is only employed in Japan.

Older U.S. plants built in the 1970's and early 1980's utilize liquid-state fermentation to convert beet or cane molasses into citric acid. In comparison, most newer plants use submerged-culture or deep-fermentation processes. The submerged-culture process can operate on a variety of carbohydrate feedstocks including corn, cane sugar, and wheat.

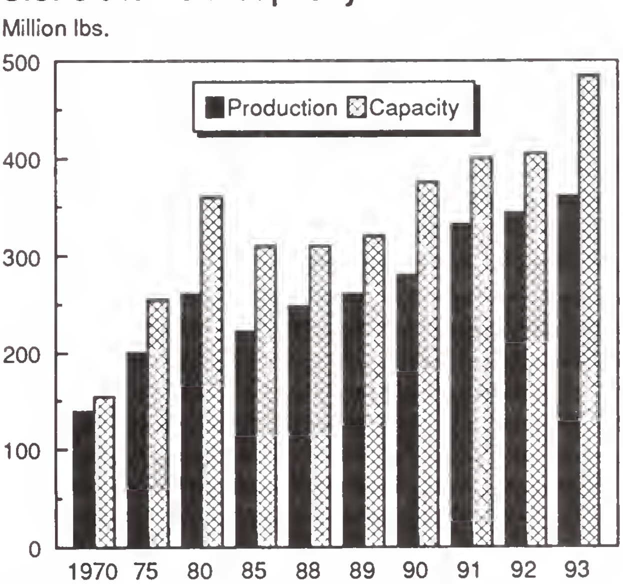
Current domestic consumption of citric acid is estimated at 360 million pounds annually. This requires approximately 16 to 18 million bushels of corn. In comparison, 414 million bushels of corn were used to make high fructose corn syrup, a corn-derived sweetener, in 1992/93. Cornstarch is the main feedstock for biobased citric acid, with a small portion, under 10 percent, produced from citrus (fruit) waste. Cornstarch fermentation in corn wet-milling plants typically yields 18 to 20 pounds of citric acid per bushel of corn.

The U.S. citric acid industry has undergone a substantial change in the past 4 years, in both producers and production capacity. In early 1990, Cargill, Inc., entered the business with a new, 5-million-pound-per-year plant at Eddyville, IA. Cargill is currently expanding the capacity of its Eddyville plant from 80 million to 160 million pounds per year. In late 1990, Archer Daniels Midland (ADM) acquired the citric acid and citrates business of Pfizer, Inc. The purchase included a plant at Southport, NC, and one in Ireland, but excluded a Groton, CT, plant. ADM has since expanded its Southport plant's capacity by 80 million pounds to 180 million pounds. The third major producer of citric acid in the United States is the Harmann & Reimer Corporation. Harmann & Reimer operates two U.S. plants, one in Dayton, OH, and the other in Elkhart, IN. These two facilities have a combined annual capacity of approximately 150 million pounds.

Given domestic consumption of 360 million pounds and production capacity until recently of 410 million pounds (excluding Cargill's 80-million-pound expansion), U.S. citric acid firms have been approaching 90 percent of capacity (figure 6). In recent years, imports have played a significant role in the U.S. market, contributing 15 percent of U.S. demand. A pound of citric acid currently has a market value of 76 cents. According to industry sources, prices are expected to increase to 88 cents per pound by 1995/96.

Figure 6

U.S. Citric Acid Capacity and Production

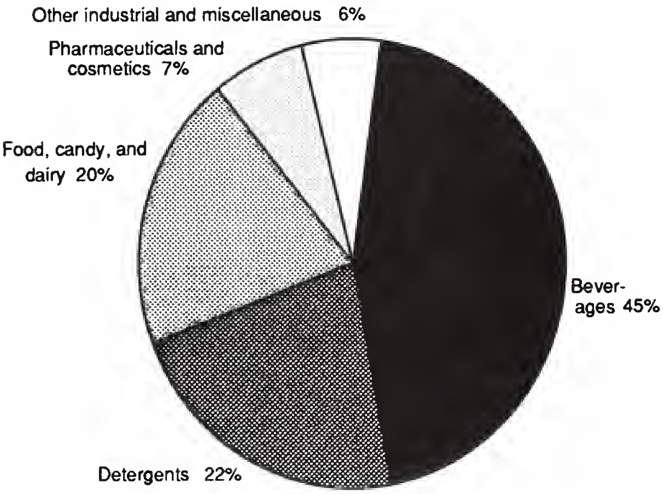


Source: Irshad Ahmed, Institute for Local Self-Reliance, Washington, DC, May 1994.

The beverage market accounts for approximately 45 percent of citric acid used in the United States, with another 20 percent used by the food-confectionery industry, 22 percent in the soaps and detergent industry, and the remaining 13 percent in a variety of industrial processes and product applications (figure 7). As mentioned above, the food industry uses citric acid as an acidulant, mostly in carbonated beverages, jams, jellies, and other foodstuffs. While overall food and beverage markets are relatively mature, this segment has regularly contributed 2 to 3 percent a year to the growth in citric acid demand. This increased demand has recently taken the form of new consumer products, such as "natural" beverages, "clear" beverages, and "sports drinks."

Figure 7

End Uses of Citric Acid in 1993 1/



1/ Use in 1993 was 360 million pounds.
Source: Irshad Ahmed, Institute for Local Self-Reliance, Washington, DC, April 1994.

Eutrophication of streams and lakes by phosphates in soaps and laundry detergents has resulted in a drastic increase in the demand for sodium citrate, a derivative of citric acid. Unlike phosphate-containing formulations, detergents with sodium citrate do not require high-cost, energy-intensive sewage treatment. Sodium citrate acts as a bulking agent in detergents and is widely used in liquid laundry detergents. The demand for sodium citrate in liquid detergents is growing 3 to 5 percent per year.

Citric acid has also captured a portion of the pharmaceutical industry. It is used in a variety of drugs, including the manufacture of citrates and effervescent salts. The ion-sequestering and buffering properties of citric acid are important to industry, both in product processing and end-product formulation. Industrial applications include degreasers, metal-cleaning and -finishing compounds, agricultural nutrients, oil-well acidizing, and stack-gas desulfurization. Citric acid also is used in the production of acetyl tributyl citrate, a vinyl resin plasticizer used to impart flexibility to molded plastic products.

With Cargill's new capacity on line, the U.S. supply of citric acid is adequate to meet demand for the foreseeable future. Because no significant demand changes are expected in the food and beverage industry, the U.S. demand for citric acid is expected to track the growth of the U.S. Gross Domestic Product, which is projected at 3.6 percent for 1994. Worldwide demand is expected to be slightly higher, between 5 and 6 percent. Increased environmental regulation could push these estimates upward. Moreover, since major U.S. producers are expanding their capacities, the United States may soon become a net exporter of citric acid, rather than a net importer. [Douglas Beach (202) 219-0428, Tom Tice (202) 219-0840, Allen Baker (202) 219-0840, and Irshad Ahmed (202) 232-4108]

Plasticizers, Paints, and Biodiesel Expand Markets for Fats and Oils

About 15 percent of the plasticizers produced in the United States are derived from plant matter, mostly vegetable oils, and the market is growing 3 to 5 percent a year. The market for epoxidized soybean oil may expand tremendously if it can be incorporated into paints and coatings to replace volatile solvents. U.S. Environmental Protection Agency regulations issued in the last few years require diesel fuel to meet reduced sulfur standards and engine-emission requirements, which may open niche markets for biodiesel.

Use of Plant-Based Plasticizers Is Small but Growing

Plasticizers are organic compounds added to plastics to improve workability during fabrication and to extend or modify the natural properties of the original resin. Plasticizers make molding and shaping plastic resins into consumer end products, such as bottles and plastic bags, easier. Plasticizers also impart flexibility and other desired properties to the finished product.

Plastics contain about 2 to 5 percent plasticizers, 1 to 2 percent other additives, and 10 percent or more builders to control properties and cost. One of the most important uses of plasticizers is molding polyvinyl chloride (PVC), a plastic widely used in construction, electrical, consumer, packaging, transportation, and medical applications. PVC resin is very brittle and cannot be molded without plasticizers.

Of the 1.6 billion pounds of plasticizers produced in the United States in 1990, 230 million pounds, or 15 percent, were derived from plant matter. Most of these plant-based materials are from vegetable oil feedstocks (table 3). Epoxidized soybean oil (ESO) accounted for 100 million pounds, while acrylic esters, which are derived from a variety of plant sources (including wood extractives and coconut oil), accounted for 74 million pounds. Over a dozen companies produce ESO. The market for plant-derived plasticizers is growing 3 to 5 percent a year.

ESO and mercaptoethyl oleate, a vegetable-oil-based compound, are proven plasticizer/stabilizers for PVC. Metallic stearates, made from vegetable oils such as coconut and palm oils, are currently used in polystyrene, polypropylene, and acrylonitrile-butadiene-styrene copolymers. Sebacate and azelate esters, both vegetable-oil derived, impart low-temperature flexibility to thermoplastics.

The price of plant-based plasticizers has come down in the past 10 years, and generally ranges from 50 cents to $3 per pound. These plasticizers have properties similar to higher quality, property-specific petrochemical plasticizers and compete at the upper end of the price scale. Research into new processes promises to reduce the price of plant--based plasticizers in the future. For example, improvements in esterification, a process used by the chemical industry to make surfactants and other fat- and oil-based intermediate chemicals, has the potential to produce plant-based plasticizers more cheaply.

Table 3--U.S. production of plasticizers from vegetable oil and petrochemical feedstocks, 1990

Category	Production
	Million pounds
Epoxidized soybean oil	100
Epoxidized linseed oil	6
Other epoxidized esters	14
Oleic acid esters	12
Stearic acid esters	8
Palmitic acid esters	6
Sebacic acid esters	6
Isopropylmyristate	4
Other acrylic acid esters	74
Total	230
Petrochemical-based plasticizers	1,324
Total plasticizers	1,554

Source: Irshad Ahmed, Institute for Local Self-Reliance, Washington, DC, May 1994.

Another example of increased commercial activity in plant-matter-based plasticizers is the development of acrylates. Plant-based acrylates were developed by Battelle Memorial Institute's Pacific Northwest Laboratory (Richland, WA). Battelle derives its acrylates from blackstrap molasses, a byproduct of sugarcane production, in a process that uses bacterial and chemical means to convert the residue sugars into acrylates. Battelle currently sells its acrylates, which are used as plasticizers in plastics and as a plasticizer-resin in acrylic paints, for 70 to 75 cents a pound.

Epoxidized Soybean Oil May Substitute for Volatile Solvents in Paints and Coatings

The market for ESO could expand tremendously if it is incorporated into paints and coatings to replace volatile

solvents. The Clean Air Act Amendments of 1990 (CAAA) require paint manufacturers to reduce volatile organic compounds (VOC's) in their formulations. Petroleum-based toluene, xylene, methyl ethyl ketone, and methyl isobutyl ketone must be eliminated entirely. Chlorinated solvents must be removed from formulations because of their ozone-damaging potential. Manufacturers must also make efforts to reduce emissions of several other pollutants. The actual limits on VOC content depend upon where the coating is used and the particular category. Regulations issued by the U.S. Environmental Protection Agency (EPA) list over 50 different paint categories, each with its own VOC limit. However, implementation of the EPA rules is left to the states. Consequently, current VOC limits vary by location, but there is an effort underway to settle on a national standard. National rules could be in place as early as January 1996.

Given these and anticipated future regulations, researchers and paint formulators are looking at ESO derivatives as reactive diluents. In paints and coatings, the diluent (solvent) evaporates, leaving the solid covering. While they can substitute at least partially for organic solvents, ESO derivatives react chemically to become part of the finish, hence less evaporation and reduced VOC's. EPA regulations now in effect require reducing VOC evaporations from 500 grams per liter of finish to less than 200 grams. Some ESO-based, reactive-diluent finishes have evaporation rates of less than 100 grams per liter.

To be successful, ESO reactive diluents must be able to produce an effective, solid covering when manufactured in commercial quantities, as they appear to do when tested under laboratory conditions. Each new formulation will be tested for VOC emissions by the American Society for Testing and Materials (ASTM) under EPA-designated procedures. However, ESO diluents will drive up the cost of paints and coatings. How much has not yet been determined, but ESO-based products should have better coverage (i.e., cover more area per gallon) than conventional paints, countering at least some of the higher cost. It remains to be seen whether coverings that include ESO reactive diluents can meet performance objectives and also be price competitive.

Typical paints are about 70 percent solvent and 30 percent solids. The redesigned paints containing reactive diluents would be about 50 percent solvent and 50 percent solids. Of the 50 percent solids, up to 10 percent could be ESO. By the end of the year, Ecotek Corporation is planning scale-up tests in California with finishes containing as much as 10 percent ESO.

The market for ESO diluents could reach 250 to 300 million pounds a year, more than doubling the size of the current ESO market. This estimate is based on the assumption that, of the combined 3-billion-pound-per-year market for epoxy and alkyd binders, ESO could replace as much as 10 percent of these binders in some coatings and less in others, depending on the kind of finish required and the durability expected. This is probably an upper bound, given current and expected regulations and present technology, which limits the proportion of ESO in the formulation.

One of the current problems with a higher ESO content in coatings is the so-called rubber-toughening effect. High levels of ESO would impart a more "rubbery" quality to the finish, which is undesirable in some applications. For example, it gives paints a flat appearance rather than a glossy one. However, a rubber-toughened coating would be useful when chip resistance is important, such as in automobile undercoatings, or where some flexibility is desirable, such as in bridge paints where the coating should accommodate the movement of the structure.

The rubber-toughening effect could be useful in other applications as well. The effect comes as ESO forms globules that arrest the cracking propensity of some resins. The result is a strong, light material with flexibility and resistance to fracturing. Rubber-toughened materials also could be used in manufacturing plastic composites. The major application would be as a substitute for metal parts, such as engine mountings and frames, in automobiles, appliances, and other manufactured goods where strength and weight are important considerations.

Changes in Diesel Regulations May Create Niche for Biodiesel

New EPA regulations issued in the last few years make diesel fuel subject to quality standards and engine-emission requirements, which may open niche markets for biodiesel. Before 1993, the only specification for diesel fuel was the D 975 Standard Specification for Diesel Fuel Oils issued by ASTM. In addition, refinery operations were primarily geared toward gasoline quality and output, which meant that diesel quality would vary depending on gasoline demand. (Producing more gasoline from a barrel of crude oil changes the characteristics of the diesel fuel made from that same barrel.)

According to the EPA regulations, beginning October 1, 1993, diesel fuel for on-highway uses must (1) contain no more than 0.05 percent sulfur by weight, and (2) have a cetane index of at least 40 or not more than 35 percent aromatic hydrocarbons by volume. Previously, diesel fuel averaged approximately 0.25 percent sulfur. The cetane value is a measure of the fuel's ability to self-ignite. Diesel engines perform better with straight-chain molecules that increase the cetane index. Gasoline engines, on the other hand, perform better with branched molecules, like iso-octane.

Any vehicle with a diesel engine that is designed to transport persons or property on streets and highways is subject to these regulations. High-sulfur diesel fuel may

still be sold, but it must be dyed blue and can only be used in off-road applications, including railroad, marine, construction, and agricultural uses.

In addition to adopting the federal regulations on sulfur, the California Air Resources Board and the California State Government implemented a stricter set of regulations that limit the aromatics in diesel fuel to 10 percent by volume, or to the use of alternative formulations that produce emissions equal to that standard. Small refiners, however, are allowed to meet a 20-percent aromatics standard.

As part of the CAAA, on-road diesel engines (1993 model year and later) must meet emission limits on particulate matter, carbon monoxide, hydrocarbons, and nitrogen oxides (table 4). Smoke (opacity) is limited to 20 percent in acceleration mode, 15 percent in lug mode, and 50 percent at peak. Research and testing continues to evaluate how biodiesel and biodiesel/petroleum-diesel blends may be used to meet these new Clean Air Act requirements.

Table 4--Emission standards for on-road diesel engines 1/

Engine type and pollutant	Emission standard
	Grams per brake horsepower hour
On-road diesel engines	
Particulate matter	0.25
Carbon monoxide	15.5
Hydrocarbons	1.3
Nitrogen oxides	5.0
Buses	
Particulate matter	
1993	0.10
1994	0.07
1996	2/ 0.05
Carbon monoxide	15.5
Hydrocarbons	1.3
Nitrogen oxides	5.0
All heavy-duty diesel engines, including buses	
Nitrogen oxides	
1998	4.0

1/ 1993 model year and later. Some standards become stricter in later years. 2/ 0.05 grams per brake horsepower hour for certification and 0.07 grams per brake horsepower hour for in-use testing.

Source: Federal Register, Vol. 58, No. 55, Wednesday, March 24, 1993, pp. 15781-802.

Low-Sulfur Diesel May Create Lubricity Problems

The recent change to low-sulfur diesel fuel for on-road vehicles has raised questions about the lubricating properties of the reformulated fuel and its reaction with elastomers in fuel injection equipment. The lubricating properties of diesel fuel are important, especially for users of rotary-type fuel pumps, which are common on trucks, tractors, light-duty vans, school buses, and other diesel-powered vehicles with less than 190 horsepower. Rotary fuel pumps depend on the fuel itself for lubrication. Therefore, problems with low-sulfur diesel could include premature rotary pump wear, plugged injector nozzles, and low power. After the mandated change to low-sulfur diesel fuel, many reports of o-ring failure and other potential injector problems surfaced. The concerns are being attributed to the refining process used to remove sulfur, called hydrotreating, which apparently leaches out some of diesel's lubricating components.

A representative of the American Association of Diesel Specialists reports that there seem to be serious problems with lubricity in California, where the seizing of fuel pumps has increased dramatically. This problem seems to be concentrated in that state, which has more stringent aromatic standards than the rest of the country. Reports from the California Diesel Fuel Task Force indicate that problems have occurred in all types of light-, medium-, and heavy-duty engines (1).

Given these concerns, the International Standards Organization formed a Diesel Fuel Lubricity Committee to determine a standard, analytical-test method for the measurement of lubricity. The committee's intent is to eventually set a lubricity standard for diesel fuel. Currently, there are no specifications or requirements for diesel fuel lubricity.

Preliminary results are available from a biodiesel lubricity study funded by soybean checkoff funds and managed by MARC-IV, a biodiesel consulting firm in Bucyrus, KS. Test results from the scuffing-ball-on-cylinder-lubricity-evaluator (BOCLE) machine indicate a 20-percent biodiesel blend significantly improved lubricity with both low-sulfur/high-aromatic and low-sulfur/low-aromatic diesel fuel. Ten-percent biodiesel mixed with low-sulfur/high-aromatic petroleum diesel also showed significant improvement in lubricating quality. Results from the testing with low-sulfur/low-aromatic diesel, although improved, were close to the analytical variation of the test (table 5).

A field test in St. Louis, MO, has been planned to examine the lubricity qualities of biodiesel over an 18-month period in conjunction with Stanadyne Automotive Corporation and Robert Bosch Gmbh, the leading manufacturers of rotary fuel pumps. Three school buses with 7.3 Navistar diesel engines equipped with Stanadyne fuel pumps will be tested with a 20-percent biodiesel/80-

percent diesel blend, and three will serve as controls. A field test with Bosch pumps will be initiated in the near future.

Biodiesel Is Nontoxic and Biodegradable

Biodiesel is considered nontoxic and biodegradable. Procter & Gamble, Inc., and Midwest Biofuels, Inc., a subsidiary of Interchem Environmental, Inc., (Overland Park, KS) have released data quantifying the safety of soybean-oil-based biodiesel (methyl soyate) (table 6). Due to these nontoxic characteristics and its biodegradability, biodiesel is being considered as a fuel source in geographic areas that are environmentally sensitive, such as rivers, bays, parks, and forests.

In addition to research conducted in Europe, USDA's Cooperative State Research Service and the U.S. Department of Defense are funding biodegradability research on biodiesel. Respirometry experiments at the U.S. Army Natick Research, Development, and Engineering Center (Natick, MA) were conducted to determine the biodegradability of methyl soyate in an aqueous medium. The results, which are reported on the basis of carbon dioxide evolution, show that after 8 days the conversion was 55 percent, with degradation continuing. Similar research at the University of Idaho indicates that the degradability of biodiesel (rapeseed methyl esters and rapeseed ethyl esters) is comparable to that of sucrose. The degradability of No. 2 diesel was considerably lower. [Lewrene Glaser (202) 219-0085, Alan Weber (314) 882-4512, Roger Hoskin (202) 219-0840, and Irshad Ahmed (202) 232-4108]

Reference

1. *Report of the Diesel Fuel Task Force*, presented to Pete Wilson, Governor of California, February 18, 1994.

Table 5--Lubricity qualities of petroleum diesel, petroleum diesel/biodiesel blends, and biodiesel on a scuffing-ball-on-cylinder-lubricity-evaluator (BOCLE) machine 1/

Low-sulfur/high-aromatic petroleum diesel 2/		Low-sulfur/low-aromatic petroleum diesel 3/	
Percent biodiesel added	BOCLE results 4/	Percent biodiesel added	BOCLE results 4/
	Grams		Grams
0.0	4,200	0.0	3,500
0.2	3,900	0.2	3,300
2.0	4,400	2.0	3,500
5.0	4,500	5.0	3,600
10.0	5,200	10.0	3,800
20.0	5,200	20.0	4,100
100.0	6,100	100.0	6,100

1/ Test performed by the Southwest Research Institute. These results are not an endorsement of biodiesel by the Institute. 2/ Contains less than 35 percent aromatics by volume. 3/ Contains less than 10 percent aromatics by volume. 4/ Test bias +/- 200 grams. A diesel fuel with good lubricity qualities will give BOCLE results in the 4,500- to 5,000-gram range and a bad lubricity diesel will give results in the 1,500-gram range.

Table 6. SoyDiesel (methyl soyate) toxicity data

Test	Subject	Result
Acute oral toxicity	Rats	The acute oral LD_{50} (the lethal dose for 50 percent of the rats in the test) was greater than 17.4 grams per kilogram of body weight. By comparison, table salt has an LD_{50} of 1.75 grams per kilogram.
Eye irritation	Rabbits	Application of undiluted material to the eye produced only mild transient irritation, meaning the eye returned to normal in one day or less.
Skin irritation	Humans	A 24-hour patch test indicated that undiluted methyl soyate produced very mild irritation. The irritation was less than that resulting from a 4-percent aqueous soap solution.
Aquatic toxicity	Bluegills	The 96-hour LC_{50} (lethal concentration) was greater than 1,000 milligrams per liter. This level is in the "insignificant" classification, according to the Registry of the Toxic Effects of Chemical Substances published by the National Institute for Occupational Safety and Health.

Source: Biodiesel Alert, November 1993.

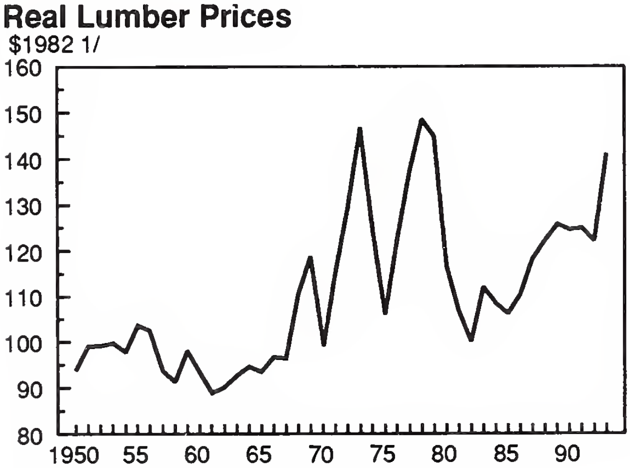
As Longrun Lumber Prices Rise, Industry Shifts To Engineered Wood Products and Explores Other Materials

Real lumber prices are volatile but trending upward in the long run, reflecting lower public timber harvests, speculation, and other supply and demand factors. In response, engineered wood products and wood substitutes are becoming more attractive. Steel framing is making some inroads into traditional lumber use, but wood remains the predominant building material for residential construction in the United States.

The residential construction industry, which is dominated by individual builders and its associated supply industries, accounts for 12 percent of U.S. Gross National Product. Over 60 percent of all lumber, plywood, and other wood-based building products is used to build, repair, or alter homes. Wood is the primary building material for most residential construction in the United States. Nearly all single-family houses and most multi-family housing units are built of wood. Recent reductions in timber harvests from federal lands and environmental concerns about timber harvests in world rain forests have led to questions about the adequacy of timber supplies.

Concerns about the availability of wood products for homebuilding have occurred before. Often, these concerns are triggered by violent fluctuations in lumber prices. The real (adjusted for inflation) price of lumber has risen rapidly in response to short-term supply and demand imbalances (figure 8). In the 1970's, real lumber prices increased 50 percent, and nominal prices more than doubled. After declining sharply in the 1980's, prices remained relatively stable until 1993, when increased housing construction, combined with reduced harvests in National forests and other factors, led to a dramatic rise in prices. Although the price of some lumber products nearly doubled, the real price of lumber is still less than the 1970's peaks.

Figure 8
Real Lumber Prices



1/ Nominal numbers deflated by the Producer Price Index.

Wood Framing Still on Top

Efforts to industrialize the housing industry have led to promotion of alternative materials and construction methods that are more amenable to factory mass production. These efforts were particularly strong during the housing shortage after World War II and during the Operation Breakthrough housing program, which was sponsored by the U.S. Department of Housing and Urban Development's (HUD) in the early 1970's. However, wood-framed housing has stood the test of time and remains the dominant technology for home construction in the United States.

Since the late 1920's, people have tried to industrialize homebuilding by using new materials, such as concrete products, metals, and even plastics, to replace wood as the basic building material. Two of the most noteworthy alternative systems used metal as the basic building material. They were Buckmeister Fuller's Dymaxion House and the Lustron House. The Dymaxion house used advanced engineering principles and metal stress-skin like aircraft construction. The Lustron house used porcelain-enameled steel panels as the basic building material. Both were financial and market disasters for the developers and their investors.

Other attempts were made in the 1950's and 1960's to use nonwood materials, but none were a lasting success. A number of houses were built with concrete or cinder blocks, but they lost popularity because of problems with insulation and alteration. In 1969, HUD established Operation Breakthrough to encourage greater efficiency and the use of new technology in housing. Of over 20 projects, only two reached commercialization and both used wood framing.

Wood-framed housing systems are successful because they can be adapted to components, such as doors, windows, or trusses, that are manufactured and shipped to the site. Greater use of prefabricated housing components, and even entire housing units, generally has made wood-framed housing competitive with other materials. In addition, most houses use roof trusses and many use floor trusses that conserve on wood use.

Engineered Wood Products Increase Their Market Share

Engineered wood products have evolved in the last 30 years to provide replacements to traditional wide-dimension wood that have durability, strength, and consistent performance characteristics. These products combine wood veneers and fibers with adhesives to make wide-dimension lumber, beams, joists, headers, and other structural products. Advances in adhesive technology have made these products possible. For example, waterproof phenolic resins allowed the development of composite products for exterior use. Engineered wood products also make use of lower quality wood resources, which may come from smaller trees or from species that have not been fully utilized. These products can be substituted into wood building systems using the same general techniques of construction, thus having the advantage of fitting into the existing technological and distribution system.

One of the most promising innovations are wood I-beams, which are typically made from 2- by 4-inch, machine-stress graded lumber or laminated-veneer-lumber (LVL) flanges that are grooved to receive oriented-strand board (OSB). I-beams can be used to replace wide-dimension lumber for headers, rafters, floor or roof joists. A number of manufacturers are commercially producing I-beams with a wide range of characteristics, designs, and materials standards. For example, Boise Cascade Corporation has developed a new framing system utilizing the firm's I-beams and other engineered wood products: BCI Joist wood I-joists, Wersa-Lam vertically laminated veneer lumber, and Versa-Lam Plus horizontally laminated lumber. Several I-beam manufacturers have received HUD approval under the auspices of the Department's Technical Suitability of Products Program.

The advantages of I-beams are uniformity, light weight, dimensional stability, length of span, speed of construction, installation with conventional tools, and low cost. The estimated cost of a 2- by 12-inch I-beam is about $1.50 per linear foot. Based on 1993-average prices, 2- by 12-inch-dimension lumber costs about $2 per linear foot.

A new type of engineered wood product called parallel-strand lumber (PSL) became commercially available in Canada in 1988. PSL was developed by MacMillian-Bodel Ltd. of Canada, which now makes the product in the United States under the name Trus Joist MacMillian. The PSL manufacturing process uses veneers cut into 1/2-inch strands, which are then aligned and pressed into blocks with adhesives and cured under pressure with heat from microwaves. The blocks are cut into various sizes, depending upon the application.

The main advantage of PSL is its strength and design flexibility. PSL products are three times as strong as conventional sawn timber and could challenge steel and concrete as a building material. The products also have an attractive appearance and can be used for exposed applications. Costs of 4- by 12-inch PSL products range from $6 to $7.50 per linear foot.

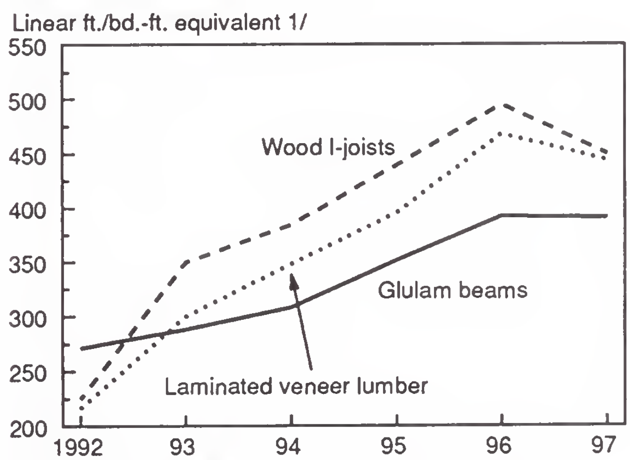
Glue-laminated (glulam) materials consist of 1- or 2-inch lumber that is glued together in stacks to a desired shape and size. The individual, laminated pieces may also be joined at the ends with adhesives for longer lengths. Glulam products emerged in the 1950's for use as beams, columns, and arches for heavy timber-framed structures, such as churches, park shelters, and outdoor pavilions. Curved glulam beams that span over 500 feet have been used in sports and multi-purpose arenas. Presently, glulam materials are used for load-bearing beams and conventional wood construction, especially when the beam is exposed for aesthetic purposes.

The demand for engineered wood products is growing dramatically. The market for wood I-joists and beams, LVL, and glulam is expected to double between 1992 and 1997, according to the American Plywood Association. Wood I-joists are projected to double from 225 million to 450 million linear feet (figure 9). High lumber prices could further boost I-joist use. LVL sales are expected to grow from 216 million board feet in 1992 to 444 million in 1997. Use of glulam beams is expected to increase from 271 million board feet to 391 million during the same period. Although new to the market, PSL use is also expected to climb. The expected decline in demand between 1996 and 1997 shown in figure 9 is due to a projected decrease in housing construction.

A study by George Carter and Affiliates estimated that the number of builders using some type of engineered wood product rose from 38 per cent in 1989 to 77 percent in 1992. Carter predicted that LVL usage would rise by 137 percent by the year 2000, I-joist and beams by 140 percent, and glulam by 30 percent.

Figure 9

Projected Use of Engineered Wood Products



1/ Linear feet for I-joists and board-feet equivalent for glulam beams and laminated veneer lumber.

Source: American Plywood Association.

Wood panel composites, such as particleboard, OSB, and waferboard, have also replaced lumber and softwood plywood in a number of construction applications. The next generation of composite materials, made with recycled wood and newspaper fibers and straw and other biomass fibers, are now appearing on the market. These composites will be discussed in further detail in the December 1994 issue of this report.

Alternative Building Systems Are Evolving

Steel, concrete, and plastic-containing materials have made inroads into nonresidential and residential construction. Steel is strong, durable, noncombustible, and versatile. It is already used for many commercial lodging structures and high-density, multi-family, residential buildings, where fire codes are an important consideration. A large construction company in Hawaii announced that it would use steel framing in its new projects. Steel framing is used in a substantial proportion of Japanese multi-family home-building. Steel also has advantages for light-weight, prefabricated housing systems, which could be used worldwide because of low weight-to-strength properties.

The disadvantages of steel systems are that special tools and fasteners are needed for construction, and residential construction workers are not accustomed to working with steel. Also, local officials are unfamiliar with steel framing's capability. More engineering analysis is needed for builders to adopt steel systems. There are also problems with noise transmission and heat conductivity. Nevertheless, if wood prices continue to rise rapidly, steel framing may become more competitive with wood systems.

Nu-Steel (Suwanee, GA) has successfully marketed steel framing systems in Australia and hopes to establish 500 marketing outlets in the United States in the next 10 years. Mitek Industries (Chesterfield, MO) has developed cost-effective steel and truss framing systems that compete with wood in light-frame construction, and the firm offers computer design and engineering assistance. Tri Steel Structures, Inc., (Corinth, TX) plans to triple its production of steel-framed houses from 500 units in 1990 to 1,500 in 1994. The National Association of Home Builders estimates that the share of steel-framed houses could expand from less than 1 percent to 5 to 15 percent in the future if lumber prices continue to rise. Other systems combine steel and wood in integrated systems to take advantage of the best properties of both materials.

Concrete systems have been used for many years for nonresidential building and for large, residential buildings. Concrete has been used for single family houses in moderate climates, such as in Florida. However, several new systems have been developed to increase the insulation value of concrete and masonry walls by incorporating foam insulation into the building systems. Light-weight ceramic/concrete systems have been developed and used in Japan for manufactured housing.

Another system for residential construction utilizes foam-core structural panels, which are a sandwich of OSB outer panels separated by a light-weight, thick, low-density core, such as polystyrene or polyurethane foam. Sandwich panels were originally developed by USDA's Forest Products Laboratory in the 1930's. Work on the concept continued in the 1950's and 1960's, until an established system for building was developed. A number of buildings, including homes, are now constructed using the foam-core system. Foam-core structural panels can be used in conjunction with heavy-timber framing that does not have load-bearing stud walls. The advantages of this system are speed of construction, high insulation value, wood conservation, and compatibility with existing wood products.

The National Association of Home Builders Research Foundation is studying three demonstration foam-core homes built in Desert Hot Springs, CA, by Banter Building Products, Inc., (Santa Anna, CA). The 1,987-square-foot houses were built with wall and roof panels, so there are no rafters or trusses and, consequently, there is room for a 250-square-foot loft. The panels themselves are the structural load-bearing system. They are 2.5 times as strong as conventional construction, which makes them more resistant to earthquake damage. The foam acts like a web and the OSB skin like an I-beam. The foam-core construction also offers superior insulation efficiency. The panels themselves have high insulation values, plus they reduce air infiltration because they fit so tightly together.

Researchers from the Massachusetts Institute of Technology's Innovative Housing Constructions Technology Program recently designed and constructed a demonstration house that uses a net-shaped-roof component system using foam-core panels. Tests indicate that the fairly complex roof system was easy to construct in a factory and could be installed in 3 or 4 hours. The demonstration house has performed well through two New England winters. Foam-core panels show real promise as an alternative housing system that eliminates the need for wide-dimension lumber and is yet compatible with standard wood-building techniques.

Additional tests of wood-frame versus foam-core-panel construction are being conducted for the National Renewable Energy Laboratory, the Structural Insulation Association, and the Modular Building Institute by Modular Building Systems (Arlington, TX). The objective is to compare identical modules for energy efficiency and performance. In another project, Shell Building Systems (Valley Ford, CA) completed a California winery building in 79 hours, compared with 4 to 6 weeks required for conventional construction. The company had already completed a 49,000-square-foot apartment and office complex for $2.20 per square foot less than conventional construction costs, with heating and cooling expenses cut in half. [Thomas C. Marcin (608) 231-9366]

More Uses for Taxol and Neem

The drug Taxol has recently been approved by the Food and Drug Administration for treatment of breast cancer in addition to ovarian cancer. Pending FDA approval, new methods of production will put the issue of harvesting Pacific yew trees to rest. Neem-based biopesticides are being introduced for use on food crops.

In mid-April 1994, Taxol, previously approved for the treatment of ovarian cancer, was also approved by the U.S. Food and Drug Administration (FDA) to treat breast cancer. Treating other forms of cancer with Taxol is still being explored.

With the approval for use on breast cancer, the demand for Taxol is expected to increase. The number of patients being treated with Taxol is already on the rise, as the drug is now commercially available for both breast and ovarian cancer. Patients may receive Taxol treatment from their own doctors as well as through the National Cancer Institute (NCI). NCI is now completing smaller scale studies and moving on to larger (Phase III) studies, in which even more patients will be treated. Currently, NCI receives all of its Taxol from Bristol-Myers Squibb (BMS).

Will Needles Be a Source of Taxol in the Future?

To date, deriving paclitaxel (the bulk drug containing Taxol) from the bark of the Pacific yew tree is the only FDA-approved process. The leading supplier is Hauser Chemical Company, currently the sole supplier of paclitaxel to BMS. However, BMS has announced that it will not renew its contract with Hauser for paclitaxel from Pacific yew bark when the current arrangement expires in August 1994. Pacific yew bark is not currently being harvested; the 1993 harvest is still supplying paclitaxel. Also, BMS does not anticipate additional harvesting in 1994. This is due in large part to recent advances in semi-synthetic production methods, particularly needle- and twig-derived paclitaxel. Such a process is currently awaiting FDA approval and, if granted, will supply BMS with a precursor used to produce Taxol.

BMS, working with an Italian natural products company, has successfully commercialized a semi-synthetic method using needles and twigs from European and Asian yews to produce 10-deacetylbaccatin III, a precursor of paclitaxel. Unlike the bark-removal method, the trees are not destroyed and may be reharvested in the future. Use of this process is pending completion of a small clinical test to insure safety of the product. Results will be submitted to FDA for evaluation.

Other Production Methods Also Gain Ground

Currently, BMS still has a firm hold on the U.S. Taxol market, and the competitiveness of other companies and methods depends on FDA approval and economic feasibility. However, competitiveness does seem to be increasing as individuals and organizations are applying for patents and FDA approval on specific processes and paclitaxel-like analogs and compounds.

Pharmaceutical and other biomedical research companies are involved in taxane (paclitaxel and related compounds) research and development, and combined efforts are often key to "new" taxane products. Phyton Catalytic, Inc., and BMS have agreed to continue studying paclitaxel production using Phyton's plant-cell culture technology, which is based on a patent by USDA's Agricultural Research Service (ARS). Phyton Catalytic has established a wholly owned subsidiary in Germany to begin scale-up production. Though no pharmaceuticals in the United States are commercially produced using this technology, several companies see potential for low-cost production in the future.

PHYTOpharmaceuticals, Inc., a subsidiary of ESCAgenetics, is also working on tissue culture production. This process is now entering a preclinical scale-up and commercialization agreement with Sun Hill Glucose Company, Ltd., a Korean firm that manufactures food and pharmaceutical products. This technology is still under development. The scale of production will have to rise and costs will have to come down to compete with bark and needle methods.

In addition, PHYTOpharmaceuticals and Enzon, Inc., have been working to develop new forms of paclitaxel using PHYTOpharmaceuticals' tissue culture technology and Enzon's PEGnology (attachment of polyethylene-glycol molecules to therapeutic molecules). This technology will hopefully reduce allergic reactions to treatment and increase solubility, thus shortening treatment administration time. ESCAgenetics has received a Phase I Small Business Innovation Research grant from NCI to produce novel taxoids, and has patents on its tissue culture process to produce taxoids.

Total synthesis of paclitaxel has been achieved by two separate groups using two different methods. One group, at Florida State University, used a linear approach in which the molecule is built piece by piece. The other group, at Scripps Research Institute (University of California, San Diego, CA), used a convergent strategy in which two halves of the molecule are built separately and then joined. Though both procedures are scientific break-

throughs, the complex, multi-step processes are not currently economically competitive.

International Taxane Research Expanding

Worldwide taxane research and development is growing. Foreign-based pharmaceutical manufacturers are competing for market share. Celex Laboratories, Inc., a subsidiary of Multiplex Technologies, Inc., (Vancouver, B.C.), has produced paclitaxel using hairy root cultures of Pacific yew trees. The cultures grow quickly, and contain harvestable quantities of target materials within 3 weeks. Celex has applied for U.S. and international patents, and is waiting for FDA approval. Pending approval, the company hopes to begin production by the end of 1994.

Another Canadian pharmaceutical company, Towers Phytochemical, has also entered into an agreement with Vestar, Inc., to develop, produce, and market a generic form of paclitaxel in Canada. Towers is supplying the paclitaxel, while Vestar is researching a liposomal encapsulated product.

As stated in the June 1993 issue of this report, European pharmaceutical company Rhone-Poulenc Rorer is continuing research on its paclitaxel-like compound Taxotere. Phase II clinical trial results indicate that Taxotere may be useful in treating patients with various types of cancer.

Neem-Based Biopesticides To Be Used on Food Crops

According to a Business Communications Company, Inc., (BCC) report, use of biopesticides is expected to increase as new regulatory restrictions remove some synthetic pesticides from use. As reported in the *Chemical Marketing Reporter*, BCC anticipates "soft pesticide" (pyrethoids) sales to surpass $1 billion by 2002. Other biopesticide sectors expected to grow over the next decade are bacterial, viral, and fungal pesticides.

As mentioned in the December 1993 issue of this report, seeds of the neem tree, which is native to India and Burma, have shown much promise as a natural pesticide. Azadirachtin, the seed's primary active ingredient, has been found to be effective against more than 200 types of insects while being "environmentally friendly." Azadirachtin seems to have little toxicity to mammals and many beneficial insects, and degrades quickly in the environment.

Since the U.S. Environmental Protection Agency (EPA) approved neem-based biopesticides for use on food crops in July 1993, specialty chemical manufacturer W.R. Grace and Company has registered its Neemix brand biopesticide in 39 states. Widespread commercial use may be possible in the future, as Grace announced in March 1994 that it was marketing Neemix through Helena Chemical Company in Florida for use on vegetable crops.

AgriDyne Technologies, Inc., also has entered the neem-based pesticide market. The company has patented a neem-seed refining process, as well as its own insecticide formulations. AgriDyne has registered two azadirachtin-based insecticides with EPA. These are in addition to Azatin EC, which is currently used on greenhouse and nursery crops.

In addition to pesticide uses, neem-based extracts are being tested for other applications that range from medicinal cures to agricultural uses. Folk medicine has been known to use neem to treat anything from fevers and ulcers to various kinds of tumors. Recent studies by ARS scientists have shown potential for neem oil to protect stored apples from fungal rot and slow the natural softening process. [Charles Plummer (202) 219-0886]

Energetics and Economics of Producing Biodiesel From Beef Tallow Look Positive

by

Richard G. Nelson and Mark D. Schrock[1]

Abstract: This study investigates the energetic and economic feasibility of converting beef tallow to biodiesel. An energy-profit ratio was used to measure whether tallow-based biodiesel has a net energy gain. The ratio ranged from 0.48 to 7.02, depending on the starting point of the analysis (animal growth, rendering, or transesterification) and the type of transesterification process used (batch or continuous flow). The ratio was less than 1 only when energy accounted for in the growth and maintenance of beef cattle was allocated to marketable products based on the mass of tallow in the animal. The cost of producing tallow-based biodiesel ranged from 92 cents to $1.67 per gallon, depending on the price of the tallow feedstock, the price received for the glycerine coproduct, and the type and size of the transesterification unit. With diesel prices averaging 71.2 cents during the last couple of years, biodiesel must find a market niche to compete, possibly as blends with petroleum-based diesel to meet Clean Air Act requirements.

Keywords: Biodiesel, tallow, diesel fuel, energetics, economics.

Biodiesel fuel is made by combining vegetable oils or animal fats with an alcohol, such as methanol or ethanol, and a catalyst in a process called transesterification. Production of biodiesel has the potential to partially ease U.S. dependence on fossil fuels, lessen the trade deficit associated with imported petroleum, and alleviate some of the environmental concerns affiliated with petroleum combustion.

Since 1982, domestic oil production has decreased at an average annual rate of 2 percent. During the last 12 years, petroleum imports have risen at an annual rate of 5.2 percent, resulting in a $50-billion-per-year negative petroleum trade balance. In addition, air pollution from fossil fuel combustion has come under much greater regulation since enactment of the Clean Air Act Amendments of 1990. For example, the U.S. Environmental Protection Agency's (EPA) Retrofit Rebuild Program requires urban transit fleets in heavily populated areas to retrofit engines or use alternative fuels to meet 1993 emission standards for particulate matter, carbon monoxide, nitrogen oxides, and other air pollutants (see the fats and oils section for more information).

Users of diesel fuel, such as urban transit agencies, view biodiesel as a potential option for meeting EPA's standards for urban buses manufactured in 1993 and earlier. Some industry experts believe a blend of diesel and biodiesel may be the least expensive way to meet the new air quality standards. Comparisons between biodiesel and petroleum-based diesel have shown biodiesel to be effective in reducing exhaust emissions of carbon monoxide, hydrocarbons, particulate matter, and sulfur. It may be less costly to purchase slightly more expensive biodiesel/diesel blends than to retrofit or purchase engines that burn other types of fuel, such as compressed natural gas or methanol. In addition, biodiesel can be used in existing handling facilities, unlike some other alternative fuels.

Diesel fuel accounts for over 20 percent of the transportation energy used in this country and has experienced the second largest growth rate among fuel types since 1982. On-highway diesel fuel consumption is about 21 billion gallons a year, or about 1.75 billion gallons a month (**1**).

Tallow Is a Potential Biodiesel Feedstock

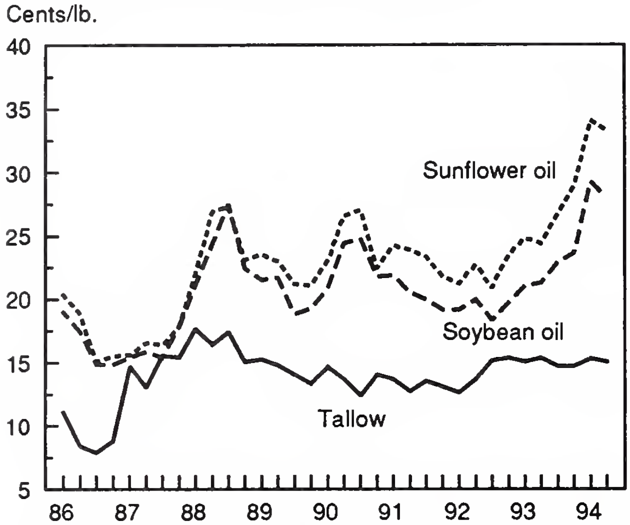
The current tallow market favors biodiesel commercialization for two reasons. First, dietary preferences are changing toward leaner meats and less saturated fat, which has put downward pressure on tallow prices. Second, tallow is cheaper than other potential biodiesel feedstocks, such as soybean and sunflower oils (figure A-1).

The majority of tallow in the United States is generated by the meat packing, poultry, and rendering industries. Census Bureau statistics show an average of 1.328 billion pounds of edible, and 3.812 billion pounds of inedible, tallow produced between 1985 and 1991. The average quantity of tallow generated per head of cattle slaughtered is estimated to range from 120 to 148 pounds. The nine largest cattle slaughtering states--Kansas, Nebraska, Texas, Iowa, Colorado, Illinois, Wisconsin, California, and Minnesota--produce approximately 80 percent of the tallow in the United States (table A-1).

[1] Nelson is a Bioenergy Specialist, Engineering Extension, (913) 532-4999, and Schrock is a Professor, Department of Biological and Agricultural Engineering, (913) 532-5580, Kansas State University, Manhattan, KS.

Figure A-1

Quarterly Average Price for Inedible Tallow, Soybean Oil, and Sunflower Oil 1/



1/ Tallow-Chicago, Soybean oil-Decatur, and Sunflower oil-Minneapolis.

The distinction between edible and inedible tallow is based on whether carcass parts are maintained and processed under USDA-approved conditions. Inedible tallow is most often used as a supplement for animal feed (62.4 percent), followed by use in fatty acids (22.4 percent), soap (10.4 percent), lubricants (3.4 percent), and other uses (1.4 percent).

Tallow has been used as one of the feedstocks tested in biodiesel experiments. For example, engine exhaust-emissions tests at the National Institute for Petroleum Energy Research used biodiesel made from soybean oil, beef tallow, and/or yellow grease (used fats and oils discarded by foodservice operations). In addition, the Fats and Proteins Research Foundation, which is supported by the U.S. rendering industry, and GraTech, Inc., a Kansas-based engineering company, are heading a project to commercialize GraTech's technology for turning rendered animal byproducts into biodiesel feedstocks. USDA's Alternative Agricultural Research and Commercialization Center, Minnesota's Agricultural Utilization Research Institute, and the National Livestock and Meat Board are the other participants in the project.

Does Tallow Make Sense From an Energy Perspective?

The feasibility of producing biodiesel from tallow involves, in part, comparing the quantity of energy required to transform tallow into biodiesel to the energy it contains. For tallow-based biodiesel to be feasible from an energetic standpoint, a net energy gain must be realized in the transformation process; i.e., the process must consume less energy than is contained in the fuel itself.

In this study, energetics are presented in the form of an energy-profit ratio, which is the amount of energy contained in biodiesel, divided by the amount of energy required to transform tallow into the fuel. All energies are expressed on a thermal (Btu) basis. A ratio greater than 1 indicates a favorable energy conversion, while a value less than 1 indicates an energetic liability.

Determining the energy-profit ratio associated with converting tallow to biodiesel fuel is a function of the starting point of the analysis (table A-2). Case 1 is concerned only with transesterification; both batch and continuous-flow processes are considered. It assumes that rendered tallow is available as a byproduct of beef production. Case 2 is concerned with the amount of energy required to process the animal fat into tallow at the rendering plant and then transesterify it. Case 3 deals with the growth and maintenance of the beef animal from conception through rendering and transesterification. Two separate methods are used to estimate the amount of energy allocated to tallow generation. Case 3a uses the cost of tallow as the basis for allocation, while Case 3b uses the mass of tallow in the animal.

The amount of energy needed to transform tallow into biodiesel involves accounting for both direct and indirect energy inputs. Direct energy inputs are the electrical and thermal energies required to operate the transesterification unit; process the tallow at the rendering plant; and pro-

Table A-1--Edible and inedible tallow production from cattle slaughter, by state, 1985-92

States	1985	1986	1987	1988	1989	1990	1991	1992
				Million lbs.				
California	201	190	166	152	145	147	135	112
Colorado	214	240	265	281	273	260	279	306
Iowa	249	246	267	240	233	229	207	205
Illinois	162	174	175	165	155	NA	NA	NA
Kanasa	774	812	783	788	777	782	753	757
Minnesota	128	127	125	137	126	131	135	126
Nebraska	701	713	697	731	727	735	789	823
Texas	769	776	778	745	732	710	701	712
Wisconsin	165	179	164	155	151	144	136	160

NA = Not available.

Source: Commercial Cattle Slaughter, National Agricultural Statistics Service, USDA.

Table A-2--Starting points for the feasibility analysis of tallow production and transformation into biodiesel

Case	Process	Feedstock
1	Transesterification (batch and continuous flow)	Rendered tallow
2	Rendering	Animal fat
3a	Animal growth	Fossil-fuel inputs for livestock feed and transportation (allocated based on COST of tallow)
3b	Animal growth	Fossil-fuel inputs for livestock feed and transportation (allocated based on MASS of tallow)

duce, process, harvest, and transport the feed and beef cattle. Indirect energies are based on a life-cycle-inventory methodology (cradle to end use), which accounts for the energy required to produce, manufacture, process, and/or distribute the raw materials, machinery, equipment, fuels, and chemicals (such as the transesterification unit, agricultural field equipment, fertilizers, and chemicals) needed to produce methyl tallowate (tallow-based biodiesel). Indirect energy inputs also include the energy content of any raw material feedstocks sequestered in these manufactured products.

Case 1. Calculating the energy-profit ratio for transesterification depends on the type of process employed. The batch-type process requires much less thermal and electrical inputs than the continuous-flow process developed by GraTech, Inc. The energy-profit ratio was determined to be 3.06 for the continuous-flow unit and 7.02 for a batch-type transesterification unit (table A-3).

The energy-profit ratios of Cases 2 and 3 are directly affected by the type of process (batch or continuous flow) used to transesterify the tallow, because of the different amounts of energy consumed by each process.

Case 2. Rendering plant energetics quantify the electricity and natural gas used to render animal fat into tallow. Operations include crushing and/or grinding, cooking, pressing, and centrifuging the animal fat before it is acceptable for transesterification. The energy-profit ratio is 1.35, when considering the electrical, thermal, and indirect energies associated with rendering plant operations, as well as energy required in the continuous-flow transesterification process. The energy-profit ratio is 1.79, when energies associated with batch transesterification are taken into consideration.

Case 3. Energetics associated with the growth and maintenance of the beef animal from conception through transesterification involve accounting for the energy required to produce, process, and transport feed components and to transport the animal from the pasture to the feedlot and rendering plant.

Typical feed components and quantities consumed by cattle and their associated breeding stock in Kansas throughout their lifetimes are 1.24 tons of irrigated corn, 0.57 tons of dryland grain sorghum, 0.04 tons of soybean meal, 0.67 tons of irrigated alfalfa, and 1.59 tons of sorghum silage. Both direct and indirect energies were determined for the production inputs for these crops, such as machinery, fuel and lubricants, irrigation, fertilizers and pesticides, seeds, transportation, and feedlot energy. For all feed components, the energy expended per ton of feed produced was determined by dividing the energy use per acre (Btu per acre) by the crop yield (tons per acre).

In this analysis, all of the energy used to raise and maintain the beef animal was allocated to marketable products. The ratio of the market value of tallow to the total marketable value of the beef animal was estimated to be 0.022. Therefore, on a cost basis, 2.2 percent of the total energy required to raise and maintain the beef animal was allocated to tallow production. The allocation is quite different, however, when based on the mass of the animal. Approximately 63 percent of the animal's live weight at slaughter is marketable and 20.3 percent of that is edible and inedible tallow. On a mass basis, tallow received the same energy allocation as the other marketable products.

The energy-profit ratio of the animal-growth life cycle (cost-based apportioning), rendering plant operations, and transesterification is 1.13 using the continuous-flow process and 1.42 with the batch process. Considering the animal-growth life cycle (mass-based apportioning), rendering, and transesterification, energy-profit ratios were 0.48 and 0.53 for the continuous-flow and batch-type processes.

Table A-3--Direct and indirect energies and energy-profit ratios for the feasibility analysis of tallow production and transformation into biodiesel

Case	Process	Transesterification process: Batch	Transesterification process: Continuous flow
		Btu per gallon	
1	Transesterification		
	Direct energy		
	Natural gas	1,402	25,451
	Electricity	1,506	1,144
	Indirect energy		
	Sodium hydroxide	964	964
	Methanol	13,865	13,865
	Process unit	314	23
	Energy-profit ratio	7.02	3.06
2	Rendering		
	Direct energy		
	Natural gas	43,857	43,857
	Electricity	8,776	8,776
	Indirect energy	83	83
	Energy-profit ratio	1.79	1.35
3a	Animal growth (cost allocation)		
	Feed ration production and transport	15,495	15,495
	Feedlot maintenance	2,276	2,276
	Animal transport	448	448
	Energy-profit ratio	1.42	1.13
3b	Animal growth (mass allocation)		
	Feed ration production and transport	143,873	143,873
	Feedlot maintenance	21,136	21,136
	Animal transport	4,532	4,532
	Energy-profit ratio	0.53	0.48

Is Methyl Tallowate Production Economically Feasible?

The second half of the study evaluated the cost of producing tallow and processing it into methyl tallowate. Because the cost of raising and maintaining beef cattle varies within each state and throughout the nation, the cost of producing beef cattle for tallow was not included. In addition, rendering costs are embodied in the market price of tallow and were not considered separately.

Economic-feasibility analyses were conducted for three transesterification units: a batch process (173,379 gallons per year), and a 3-million- and 30-million-gallon-per-year continuous-flow process. Methodology is based on the *ANL Biomass Cost Estimation Guide* (**2**). Capital costs for both types of units include transesterification and glycerine-recovery equipment. Capital equipment costs are 80 cents a gallon for the batch unit, $1 a gallon for the 3-million-gallon unit, and 50 cents for the 30-million-gallon unit. Operating costs include materials and supplies, labor and fringe benefits, overhead, utilities and fuels, repair and maintenance, and insurance. State and federal taxes and distribution costs are not included.

The total cost for running a 30-million-gallon-per-year esterification unit is $43,506,900. With credit for the sale of byproducts (glycerine and free fatty acids/fat mix), the net annual cost is $36,666,900 or $1.22 per gallon (table A-4). Glycerine is used in a wide range of products, ranging from food, beverages, and pharmaceuticals to textiles, rubber, and plastics. The free fatty acids/fat mix can be used as a feedstock for making soap and detergents or as an animal feed supplement.

Cost-sensitivity analyses were performed to determine the effect of varying tallow prices, glycerine prices, and electrical and natural gas utility rates. For the continuous-flow transesterification units, the cost of producing methyl tallowate varied from a low of 92 cents per gallon for the 30-million-gallon-per-year unit to a high of $1.67 per gallon for the smaller unit (tables A-5 and A-6). The changes in cost between the two continuous-flow units at

Table A-4--Costs and coproduct credits for a 30-million-gallon-per-year continuous-flow process producing methyl tallowate

Item	Dollars
Real annual cost of capital 1/	3,255,000
Annual operating costs:	
Materials and supplies--	
2.25 million pounds of NaOH at 30 cents per pound	675,000
3,371,140 gallons of methanol at 55 cents per gallon	1,854,127
232 million pounds of tallow at 13 cents per pound	30,127,500
Operator labor, 8,000 hours per year at $15 per hour	120,000
Overhead and fringe benefits 2/	60,000
Utilities and fuels--	
3,520,000 kW-hours of electricity per year at 7.5 cents per kW-hour	
763,530,000 cubic feet of	264,000
natural gas per year at $3 per 1,000 cubic feet	2,290,590
26.4 million gallons of washing water per year at 50 cents per 1,000 gallons	13,200
115 million gallons of cooling water per year at 30 cents per 1,000 gallons	34,560
Maintenance 3/	300,000
Insurance 4/	150,000
Total	35,888,977
Sales and administration 5/	3,914,398
Annualized cost of working capital 6/	448,525
Total annual cost	43,506,900
Byproduct credits	
22.5 million pounds of crude glycerine at 28 cents per pound	6,300,000
6.75 million pounds of free fatty acids/ fat mix at 8 cents per pound	540,000
Total	6,840,000
Total net annual cost	36,666,900
Total transesterification cost per gallon	1.22

1/ Total capital costs are $15 million. The real annual cost of capital is a 0.217 fixed-charge rate for a 15-year-book-life nonregulated firm (30 percent equity, 10 percent debt) and no tax preferences (from ANL Biomass Cost Estimation Guide). 2/ 50 percent of direct labor. 3/ 2 percent of capital costs. 4/ 1 percent of capital costs. 5/ 10 percent of real annual cost of capital and annual operating costs. 6/ Working capital is 1/12th of the real annual cost of capital, annual operating costs, and sales and administration ($3,588,198). The annualized cost of working capital is 12.5 percent of working capital.

the same feedstock costs, glycerine prices, and utility rates can be attributed to the difference in capital costs per gallon. The batch unit had production costs that ranged from 97 cents to $1.50 per gallon (table A-7).

The price of tallow as the feedstock had the greatest impact on costs. Production costs for both types of transesterification units rose an average of nearly 26 cents per gallon when tallow prices increased from 10 to 13 cents per pound, and rose an average of 43 cents per gallon when tallow prices increased from 10 to 15 cents per pound. When glycerine prices ranged from 20 to 33 cents per pound, production-cost changes averaged slightly less than 10 cents per gallon, given set feedstock costs and utility rates.

Utility rates within the range specified did not have a pronounced effect on production costs. For specific tallow and glycerine price combinations, the difference in production costs between low and high utility rates averaged slightly greater than 2 cents per gallon for the continuous-flow units and was negligible for the batch unit.

The Outlook for Tallow-Based Biodiesel

The rendering industry in the United States generates a significant amount of tallow, approximately 5 billion pounds per year. The conversion of beef tallow into biodiesel fuel has a favorable energy balance. Production costs in this analysis ranged from 92 cents to $1.67 per gallon, depending upon the cost of the feedstock tallow (10 to 15 cents per pound), prices for the byproduct glycerine (20 to 33 cents), and type of transesterification used (batch or continuous flow).

In the past few years, diesel fuel at retail outlets has sold for an average of 71.2 cents per gallon, excluding state and federal taxes (figure A-2). For biodiesel to compete, it will have to find a market niche--possibly as a blend with petroleum-based diesel to meet Clean Air Act emission requirements.

Table A-5--Estimated cost of methyl tallowate from a 3-million-gallon-per-year continuous-flow process, with varying tallow feedstock costs, utility rates, and prices for the glycerine coproduct

Glycerine prices	Tallow prices per pound		
per pound	10 cents	13 cents	15 cents
	Dollars per gallon		
With low utility rates 1/			
20 cents	1.21	1.47	1.64
28 cents	1.15	1.41	1.58
33 cents	1.12	1.37	1.54
With high utility rates 2/			
20 cents	1.24	1.49	1.67
28 cents	1.18	1.43	1.61
33 cents	1.14	1.40	1.57

1/ 6 cents per kW-hour of electricity and $2.75 per 1,000 cubic feet of natural gas. 2/ 7.8 cents per kW-hour of electricity and $3.50 per 1,000 cubic feet of natural gas.

Table A-6--Estimated cost of methyl tallowate from a 30-million-gallon-per-year continuous-flow process, with varying tallow feedstock costs, utility rates, and prices for the glycerine coproduct

Glycerine prices per pound	Tallow prices per pound: 10 cents	13 cents	15 cents
	Dollars per gallon		
With low utility rates 1/			
20 cents	1.02	1.27	1.44
28 cents	0.96	1.21	1.38
33 cents	0.92	1.18	1.35
With high utility rates 2/			
20 cents	1.04	1.30	1.47
28 cents	0.98	1.24	1.41
33 cents	0.94	1.20	1.37

1/ 6 cents per kW-hour of electricity and $2.75 per 1,000 cubic feet of natural gas. 2/ 7.8 cents per kW-hour of electricity and $3.50 per 1,000 cubic feet of natural gas.

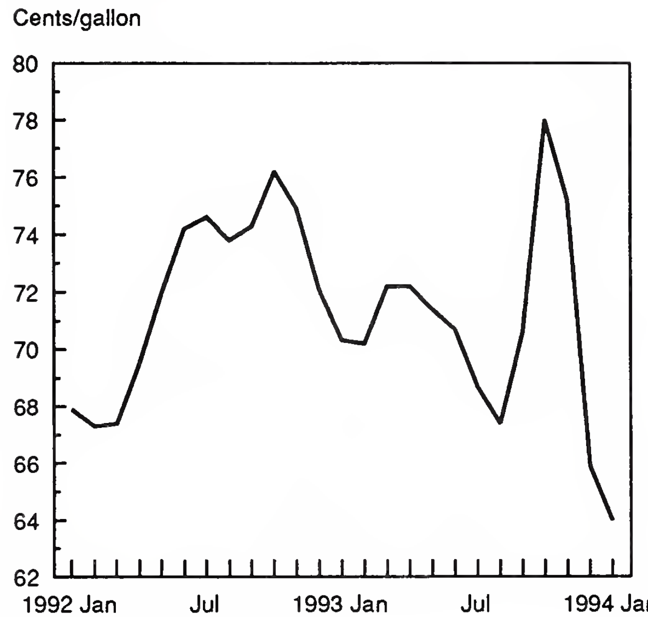
Table A-7--Estimated cost of methyl tallowate from a 173,379-gallon-per-year batch process, with varying tallow feedstock costs, utility rates, and prices for the glycerine coproduct

Glycerine prices per pound	Tallow prices per pound: 10 cents	13 cents	15 cents
	Dollars per gallon		
With low utility rates 1/			
20 cents	1.07	1.33	1.50
28 cents	1.01	1.27	1.44
33 cents	0.97	1.23	1.40
With high utility rates 2/			
20 cents	1.07	1.33	1.50
28 cents	1.01	1.27	1.44
33 cents	0.97	1.23	1.40

1/ 6 cents per kW-hour of electricity and $2.75 per 1,000 cubic feet of natural gas. 2/ 7.8 cents per kW-hour of electricity and $3.50 per 1,000 cubic feet of natural gas.

Figure A-2

U.S. Average Price of No. 2 Diesel Fuel Sold Through Retail Outlets[1/]



1/ Excludes state and federal taxes.

Source: Department of Energy, Energy Information Administration.

References

1. Davis, S. C. and M. D. Morris. *Transportation Energy Data Book: Edition 12*, ORNL-6710. Oak Ridge National Laboratory, Oak Ridge, TN, 1992.

2. Jaycor Corporation. *ANL Biomass Cost Estimation Guide, Review of Cost Estimates for Two Transesterification Processes.* McLean, VA, 1987.

Opportunities for New Coproducts From Ethanol Production

by

Miriam Cygnarowicz-Provost and Hosein Shapouri[1]

Abstract: New coproducts offer potential for improving the economics of ethanol production. However, technical challenges must be overcome before this potential can be realized. Chemicals coming from the production of ethanol, such as succinic acid and glycerine, could penetrate potentially large, new markets if prices were low enough. However, at lower prices, economic recovery of the coproducts is technically difficult. Research is underway to find new specialty chemical or foodgrade products that can be economically produced. These products will probably serve high-value niche markets, making them attractive candidates for ethanol producers.

Keywords: Ethanol production, coproducts, corn, biomass.

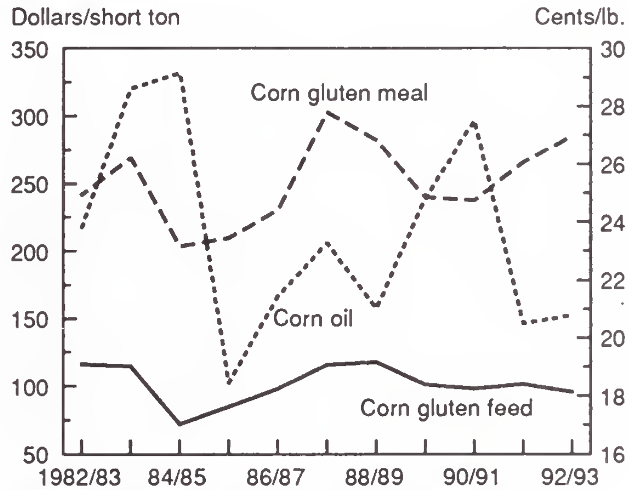
Coproducts are additional products that result from ethanol fermentation that can be recovered and sold to offset the cost of ethanol production. They are especially critical to the economics of ethanol production from corn, because corn comprises the largest portion of operating costs. The current coproduct from dry milling of corn is distillers' dried grains with solubles (DDGS), while the coproducts from wet milling are corn oil, corn gluten meal (CGM), and corn gluten feed (CGF). Dry milling yields 16.8 pounds of DDGS per bushel, while wet milling yields 1.5 pounds of corn oil, 2 pounds of CGM, and 14 pounds of CGF. Wet milling accounts for about 60 percent of ethanol production.

Why New Coproducts?

New coproducts are being sought for several reasons. The ethanol industry has increased its processing efficiency dramatically in the last several years. Although further technological innovations in processing, improvements in corn breeding and production, and the development of alternative feedstocks are expected, new profitable coproducts will make ethanol more competitive in fuel markets. The volatility in the prices of existing coproducts gives additional motivation to develop new coproducts (figure B-1).

Figure B-1

Prices of Corn Oil and Corn Gluten Feed and Meal 1/



1/ Marketing year for corn gluten feed and meal, September 1 and corn oil, October 1. Dollars per short ton for corn gluten feed and meal; cents per pound for corn oil.

Two key issues for new coproduct development are selling price and market size. Obviously, it will not be economical to separate a component from a process stream or use current coproducts as building blocks for new products unless there is a clear economic incentive. There must also be a substantial market for the new products, given the large scale of the ethanol manufacturing industry.

For example, glycerine is produced during the fermentation of starch into ethanol and will typically comprise 3 percent of the stillage (the mash remaining after the alcohol is distilled). If glycerine were recovered from the four largest U.S. ethanol plants alone, it would place an additional 140,000 tons on the market. Since current world production is 600,000 tons, additional production of this magnitude could depress market prices, which currently range from 60 to 80 cents a pound. However, the glycerine market has been unexpectedly tight, with prices

[1] Miriam Cygnarowicz-Provost is a Chemical Engineer with the U.S. Food and Drug Administration, (301) 594-3008, and Hosein Shapouri is an Agricultural Economist with USDA's Office of Energy, (202) 219-1941.

rising over 30 percent during the past year. It appears that both production capacity and new uses are growing simultaneously. As new biodiesel and sucrose polyester plants come on-line, the supply of glycerine, a byproduct of these processes, is forecast to increase 12 percent by 1997 (7).

Finally, new coproducts also should not overly disrupt the marketing of other agricultural commodities. For example, a new foodgrade coproduct made from corn protein could compete directly with protein concentrates made from soy, whey, or milk. The effects on commodity program payments are hard to predict and likely to be small. If a new corn product resulted in an increased use of corn, it could slightly lift the price of corn, and thus slightly lower corn program payments. To the extent new corn coproducts displace coproducts of other basic commodities, such as milk, new products could place slight downward pressure on those commodity prices. But since these coproducts constitute such a small fraction of the use of basic commodities, they are likely to have negligible or no effect on basic commodity prices, and thus should not alter federal commodity support payments.

Chemical Coproducts Show Promise

When ethanol is fermented from cornstarch, small amounts of other chemicals are produced, including glycerine, succinic acid, and lactic acid. In particular, succinic acid is a four-carbon dicarboxylic acid that is used to manufacture polymers and resins for lacquers, dyes, and perfumes. It is currently produced from petrochemical feedstocks, mostly in other countries (1). The market is small, 450 tons per year. However, market size could increase if succinic acid were used as an intermediate product to generate chemicals such as 1,4 butanediol (an industrial solvent), gamma-butyrolactone (a chemical intermediate and ingredient of paint removers and textile products), tetrahydrofuran (a solvent and ingredient of adhesives, printing inks, and magnetic tapes) and adipic acid (used in the manufacture of lubricants, foams, and food products). Succinic acid currently sells for $3.10 per pound.

The U.S. Department of Energy (DOE) recently presented an economic analysis of the cost to produce succinic acid from the fermentation of glucose (1). A schematic diagram of the process used to recover succinic acid is shown in figure B-2. Using this analysis, the costs of recovering succinic acid from ethanol fermentation stillage were estimated for a typical ethanol plant (table B-1). Approximately 12 pounds of succinic acid are produced from the fermentation of 100 bushels of corn. Assuming a 70-percent recovery rate, an ethanol plant that produces 58 million gallons of ethanol per year could produce over 2 million pounds of succinic acid. At the current selling price of $3.10 per pound, a profit of $3.17 million would be realized, lowering the cost of ethanol by 6 cents per gallon.

Obviously, the selling price is determined by supply and demand. Additional production of this magnitude cannot be absorbed by the market unless the price drops and demand increases. Recovery of the acid requires capital outlays to modify ethanol plants. To earn a 20-percent return on that investment, the selling price of the acid would have to be 74 cents per pound. At this price, the cost of ethanol would drop by only 0.4 cent per gallon. The real-world selling price may lie somewhere in between 74 cents and $3.10. However, this analysis demonstrates the potential benefits of recovering chemical coproducts from dilute fermentation streams.

The design presented by DOE incorporates only current technology. Some researchers believe that significant savings can be achieved if advances in membrane separation and ion-exchange chromatography are incorporated into the process.

Glycerine is present in larger amounts in the stillage than succinic acid, approximately 1 pound per bushel. Kampen has a patented process consisting of ultrafiltration, followed by ion-exchange chromatography that he claims will remove glycerine more economically (9). If supply increases and prices fall, glycerine would become more competitive with other polyols, such as propylene glycol and pentaerythritol. This should boost consumption and generate novel applications. However, a lower selling price will make it more difficult to recover glycerine from stillage economically. Still, production of glycerine would present an additional advantage to dry millers, since removing it before drying the stillage would decrease the drying time and make handling DDGS easier.

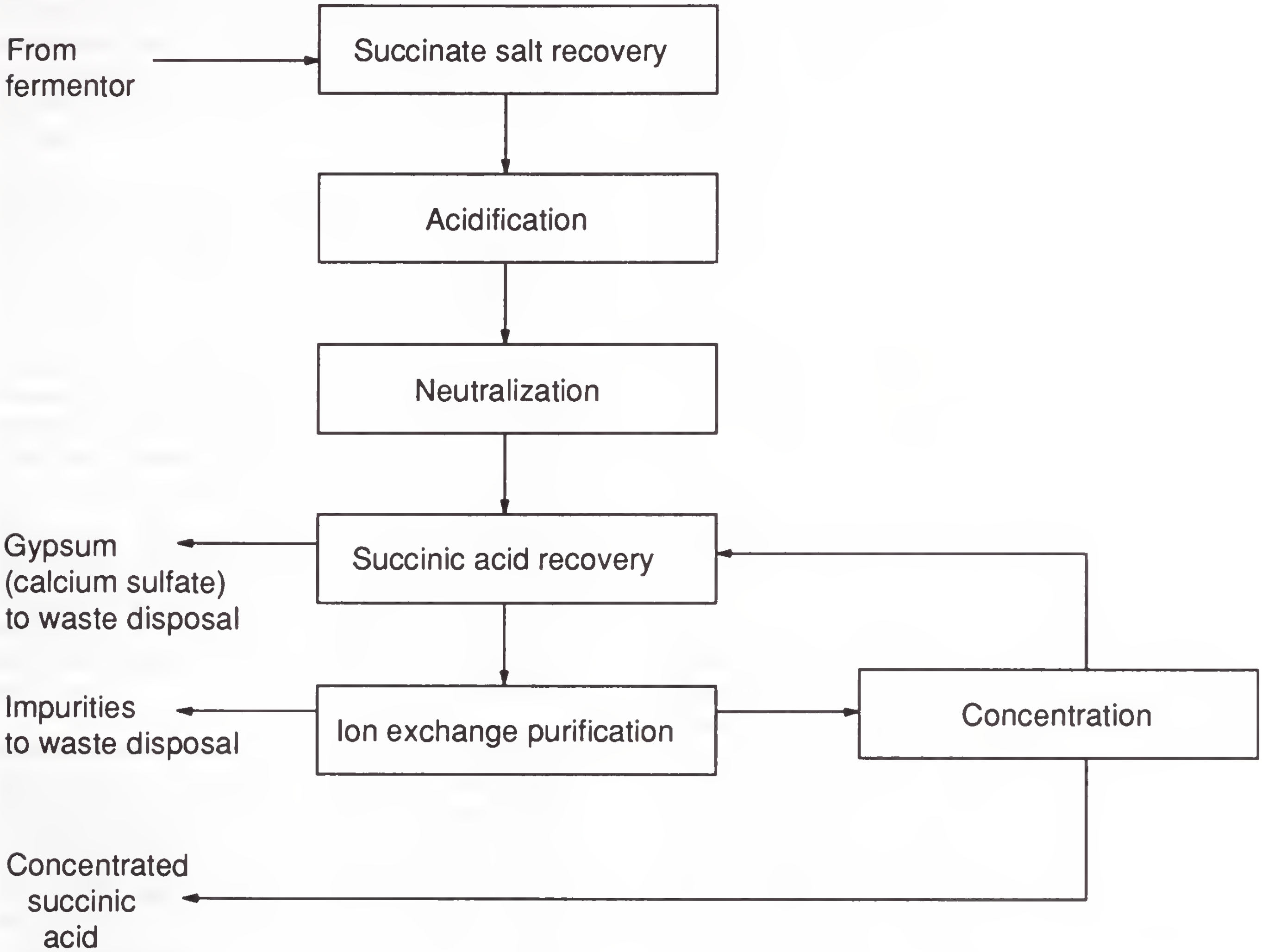
An acetic acid coproduct could be produced by an additional fermentation process, potentially using carbon dioxide as a feedstock. A process of this type is being developed by a group at the University of Arkansas (3). An anaerobic fermentation of syngas (a mixture of carbon monoxide, hydrogen, and carbon dioxide) can produce acetic acid and small amounts of ethanol with extremely high efficiencies. Capital costs are expected to be high, however, since a gaseous feedstock will require large-volume vessels. Acetic acid is used to produce plasticizers, pharmaceuticals, dyes, insecticides, photographic chemicals, and foods.

Corn Proteins Converted Into Biodegradable Films and Nutrition Supplements?

Interest is high in using the proteins from corn gluten meal as building blocks for biodegradable polymers. The major component of corn protein, zein, can be separated from

Figure B-2

Schematic Diagram of a Process To Recover Succinic Acid From Fermentation Broth



Source: (1).

Table B-1--Manufacturing cost estimate for the recovery of succinic acid from ethanol stillage 1/

Item	Unit	
Total capital investment	Dollars	1,876,000
Operating expenses:		
Raw materials	Dollars	140,000
Utilities	Dollars	132,000
Labor and labor-related expenses	Dollars	101,000
Maintenance, repair, and supplies 2/	Dollars	188,000
Waste disposal 2/	Dollars	52,000
Taxes, insurance, and overhead 2/	Dollars	169,000
Depreciation 2/	Dollars	188,000
Total	Dollars	1,198,000
Annual production	Pounds	2,009,522
Selling price	$/pound	3.10
Before-tax profit	Dollars	5,032,000
Profit	Dollars	3,170,000
Return-on-investment	Percent	179
Decrease in ethanol price	$/gallon	0.06

1/ Based on a 70,000-bushel-per-day ethanol plant and 70-percent recovery rate of succinic acid. 2/ Costs were estimated as a fraction of the total capital investment as follows: maintenance, repair, and supplies, 10 percent; waste disposal, 2.1 percent; taxes and insurance, 2 percent each; overhead, 5 percent; depreciation, 10-year, straight-line.

CGM using solvent extraction followed by crystallization. The remaining portions of CGM could be sold as low-protein animal feed.

Enzymes can be used to break down zein into polypeptides, which can be reacted with ethylene oxide, acrylamide, or methyl vinyl ketone to form durable biodegradable films. These films are professed to be superior to starch-based films, although they are more brittle and have lower tensile strength than films made from synthetic polymers.

Some scientists claim that adding plasticizers yields more flexible films (6). These films could potentially be used as wrappings for fruits, vegetables, and meats. Overall, the market for plastics is 50 billion pounds per year. It is expected that biodegradable polymers will attract an increasing, but small, portion of that market due to consumer and legislative concerns about solid-waste disposal (see the special article in the June 1993 issue of this report). Biodegradable polymers require composting to degrade, and widespread use is not expected until composting becomes more common.

Corn proteins can also be further broken down into amino acids. The amino acids could then be used as dietary supplements or fermentation nutrients. Amino acids that are known to be present in ethanol stillage include alanine, proline, valine, and leucine. The latter two are essential amino acids.

Some Coproducts Could Serve as Food Additives

The use of corn protein as a food ingredient is limited by its poor functional properties. Zein, for example, is not water soluble. Cheryan and Mannheim have developed a process that combines membrane separation with enzymatic treatment to modify zein's properties (12). The resulting product is water soluble and has improved clarity and foaming properties, making it better suited for food uses. The cost of producing these proteins has been estimated at 50 cents a pound. This compares favorably with the selling price of other purified protein concentrates, such as whey protein or casein that sell for $1 to $5 per pound. If a corn wet-milling plant converted some of its annual CGM production to zein hydrolysate, and sold the product for $1 per pound, the cost of ethanol could be reduced by 4.3 cents per gallon.

Other researchers (14) have demonstrated that levan, a polysaccharide, can be produced along with ethanol from the bacteria *Zymomonas mobilis*. Levan can be used by the food industry as a thickening agent, plasma expander, or fructose source.

Other possibilities include using CGM as a meat extender (15), or in combination with soybean meal as a textured protein product (13). Fujimoto, et al., have recently patented the use of defatted corn germ as a natural antioxidant additive for food and beverages (5).

Other potential high-value products include vitamins and colorants that could be recovered from the stillage in a membrane-separation step, followed by chromatographic separation. No economical product has been identified yet, although a commercial firm has expressed an interest in obtaining such products (16).

The yeast cell mass may also serve as a source of valuable coproducts. Examples of compounds that have been isolated from the yeast *Saccharomyces cerevisiae* include invertase (an enzyme used as a food additive), glucan (a polysaccharide with food and pharmaceutical applications), and other glycerides, phospholipids, and sterols (10). However, an economical method of recovering these compounds must be developed. The market size for these products is uncertain, but would probably be very small.

Making a foodgrade product in an ethanol plant will require some changes to meet U.S. Food and Drug Administration regulations. Additional investment would have to be made in sanitary vessels and cleaning devices, and operators would need training in foodgrade manufacturing practices.

Biomass-Based Coproducts Are Also a Possibility

The incentive to develop new coproducts for ethanol production from biomass is not as great because the feedstocks, such as paper sludge, grass clippings, and herbaceous crops, are low in cost. Biomass usually consists of cellulose, hemicellulose, and lignin. Lignin is a colorless-to-brown substance, which binds with cellulose to form the walls of plant cells. A byproduct of paper

production, lignin has found some uses as adhesives and as an asphalt extender. It cannot be broken down and fermented, and in fact, it interferes with the breakdown of cellulose to sugars by impeding the action of the enzymes. In most proposed biomass-to-ethanol plants, however, lignin is more highly valued as a fuel to be burned in the ethanol-dehydration process.

Furfural, a common industrial solvent and chemical intermediate, is produced from the breakdown of pentoses during cellulose conversion. It is a potential coproduct when ethanol is made from biomass. The market for furfural is approximately 60,000 tons annually. It is obtained primarily from the hydrolysis and conversion of agricultural feedstocks, such as oat hulls. Prices range from 65 to 75 cents per pound. Furfural possesses excellent solvent and reactive properties and could prove to be an attractive chemical intermediate if the price were low enough. It is used to manufacture lubricating oils, weed killers, fungicides, and metals.

A biomass conversion plant could potentially produce acetic acid from hemicellulose and ethanol from cellulose. Acetic acid is now made from petrochemical feedstocks. Many organisms readily convert xylose (obtained from the breakdown of hemicellulose) to acetic acid. The acetic acid, in turn, could readily be converted to calcium magnesium acetate (CMA), which is a noncorrosive substitute for road salt (2). However, CMA is expensive and does not work as well as salt in extremely cold areas.

Some of the cellulose can be used to produce a noncaloric flour substitute. This product was developed and patented by researchers in USDA's Agricultural Research Service (8). An alkaline-hydrogen peroxide treatment for oat hulls was devised that yielded a cellulose product with good functionality as a food ingredient. It can replace up to 66 percent of the flour in many products without detrimental effects on quality. This cellulose product is now being marketed by Canadian Harvest USA, which is a joint venture of DuPont and ConAgra. Millions of pounds are being sold annually for use in bakery products, such as low-calorie, high-fiber breads, breakfast cereals, tortillas, no-fat muffins and cookies, and reduced-fat pie crusts and cakes. With the new food labeling regulations, use is expected to increase.

Dale (4) has proposed several alternatives for recovering the protein-fraction of biomass feedstocks for use as animal feed. High-protein crops, such as alfalfa, are promising candidates for this process. In this case, the biomass-to-ethanol plant would be operated similarly to corn-to-ethanol plants, where the high-protein stillage is dried and sold as DDGS.

Conclusions

New coproducts offer potential for improving the economics of ethanol production. However, technical challenges must be overcome before these gains can be realized.

Chemicals, such as succinic acid or glycerine, can command a large market size, but at a selling price that makes economical recovery difficult. Foodgrade products, which can be sold at premium prices, are promising candidates for new coproducts. However, making foodgrade products in an ethanol plant will require some processing changes. Specialty products, such as biodegradable films, have perhaps the greatest potential for improving the economics of ethanol manufacture. Research is underway to find novel, useful products that can be economically produced and recovered. Although the new products will serve high-value niche markets, which will require additional effort in market research and applications development, they likely will be an attractive opportunity for ethanol producers.

Acknowledgments

The authors wish to thank the following individuals who provided information for this manuscript: H. Bungay, Rensselaer Polytechnic Institute; M. Cheryan, University of Illinois; R. K. Conway, USDA, Office of Energy; W. L. Harris, R. Villet, D. J. O'Brien, and J. C. Craig, Jr., USDA, Agricultural Research Service; N. Hohmann, USDA, Economic Research Service; R. Katzen, Raphael Katzen Associates; W. H. Kampen, K-Engineering, Inc.; M. Ladisch, Purdue University; R. Landucci, DOE, National Renewable Energy Laboratory; R. Montgomery, University of Iowa; L. Russo, New Energy Company of Indiana; and R. M. Weinzierl, Illinois Corn Growers Association.

References

1. Bozell, J. J. and R. Landucci, editors. *Alternative Feedstocks Program Technical and Economic Assessment: Thermal and Bioprocessing Components*. U.S. Department of Energy, Office of Industrial Technologies, 1993.

2. Bungay, H. R. "Product Opportunities From Biomass Refining." *Enzyme and Microbial Technology*, Vol 14, 1992, pp. 501-7.

3. Claussen, E. C. and J. F. Gaddy. "Ethanol From Biomass by Gasification/Fermentation," paper 154f. American Institute of Chemical Engineers Annual Meeting, November 1992.

4. Dale, B. E. "Biomass Refining: Protein and Ethanol From Alfalfa. *Industrial and Engineering Chemistry: Product Research and Development*, Vol. 22, 1983, pp. 466-72.

5. Fujimoto, K., K. Yamaguchi, and M. Yamaguchi. U.S. Patent 5,120,556, June 9, 1992.

6. Gennadios, A. and C. L. Weller. "Edible Films and Coatings From Wheat and Corn Proteins." *Food Technology*, October 1990, pp. 63-69.

7. "Glycerine vs Other Polyols--World Markets, 1990-2002." Colin A. Houstin and Associates, Mamaroneck, NY.

8. Gould, J. M. and L. B. Dexler. U.S. Patent 4,774,094, 1988.

9. Kampen, W. U.S. Patent 5,177,008, 1993.

10. Kollar, R., E. Sturdik, and J. Sajbidor. "Complete Fractionation of Saccharomyces Cerevisiae Biomass." *Food Biotechnology*, Vol. 6, No. 3, 1992, pp. 225-37.

11. Maisch, W. F. "Fermentation Processes and Products." *Corn: Chemistry and Technology*. American Association of Cereal Chemists, St. Paul, MN, 1991.

12. Mannheim, A. and M. Cheryan. "Enzyme-Modified Proteins From Corn Gluten Meal: Preparation and Functional Properties." *Journal of the American Oil Chemists' Society*, Vol. 69, No. 12, 1992, pp. 1163-69.

13. Neumann, P. E., B. K. Jasberg, J. S. Wall, and C. E. Walker. "Uniquely Textured Products Obtained by Coextrusion of Corn Gluten Meal and Soy Flour." *Cereal Chemistry*, Vol. 61, No. 5, 1984, pp. 439-45.

14. Reiss, M. and W. Hartmeier. "Levan Production with a Flocculent Strain of *Zymomonas mobilis*." *Food Biotechnology*, Vol. 4, No. 1, 1990, pp. 69-75.

15. Reitmeier, C. A. and K. J. Prusa. "Addition of Corn Gluten Meal and Zein to Ground Pork of Various Fat Percentages." *Journal of Food Quality*, Vol. 13, 1990, pp. 271-81.

16. Sheehan, B. T. "Nutritional Specialty Products from Ag Resources." *Bioconnection*, Summer 1991, p. 23.

List of Tables

Table 7--Flaxseed, acreage planted, harvested, yield, production, and value, United States, 1985-93

Year	Planted	Harvested	Yield	Production	Value
	--1,000 acres--		Bushels per acre	1,000 bushels	$1,000
1985	620	584	14.2	8,293	41,912
1986	720	683	16.9	11,538	39,962
1987	470	463	16.1	7,444	25,188
1988	275	226	7.1	1,615	12,200
1989	195	163	7.5	1,215	8,724
1990	260	253	15.1	3,812	21,108
1991	356	342	18.1	6,200	21,845
1992 1/	171	165	19.9	3,288	13,543
1993 2/	206	191	18.2	3,480	14,641

1/ Preliminary. 2/ Forecast.

Table 8--Linseed oil, supply and disappearance, United States, 1985/86-1993/94

Year beginning June 1	Supply			Disappearance			
	Beginning stocks	Production	Total	Exports	Domestic	Total	Ending stocks
	--Million pounds--						
1985/86	33	205	238	15	184	199	39
1986/87	39	201	240	6	183	189	51
1987/88	51	217	268	8	219	227	41
1988/89	41	170	211	12	151	163	48
1989/90	48	165	213	12	164	176	37
1990/91	37	176	213	6	167	173	40
1991/92	40	182	222	12	170	182	40
1992/93 1/	40	172	212	8	150	158	54
1993/94 2/	54	176	230	6	164	170	60

1/ Preliminary. 2/ Forecast.

Table 9--Linseed meal, supply and disappearance, United States, 1985/86-1993/94

Year beginning June 1	Supply				Disappearance			
	Beginning stocks	Production	Imports	Total	Exports	Domestic	Total	Ending stocks
	--1,000 short tons--							
1985/86	3	184	3	190	75	110	185	5
1986/87	5	185	2	192	63	127	190	2
1987/88	2	198	2	202	59	140	199	3
1988/89	3	156	11	170	63	102	165	5
1989/90	5	153	9	167	23	139	162	5
1990/91	5	162	3	170	41	124	165	5
1991/92	5	167	0	172	40	127	167	5
1992/93 1/	5	159	2	166	55	106	161	5
1993/94 2/	5	161	2	168	45	118	163	5

1/ Preliminary. 2/ Forecast.

Table 10--Rapeseed, acreage planted, harvested, yield, production, and value, United States, 1987-93

Year	Planted	Harvested	Yield	Production	Value
	--1,000 acres--		Bushels per acre	1,000 pounds	Million dollars
1987	20.0	19.4	22.7	21,981	N.A.
1988	13.5	13.1	24.1	15,822	N.A.
1989	14.0	13.6	28.2	19,143	2.01
1990	15.0	14.5	31.2	22,717	2.33
1991	18.2	15.6	20.7	16,146	1.63
1992 1/	12.0	9.8	29.5	14,455	1.45
1993 2/	7.2	6.1	24.4	7,442	0.92

N.A. = Not available.
1/ Preliminary. 2/ Forecast.

Table 11--Industrial rapeseed, supply, disappearance, and price, United States, 1987/88-1993/94

Year beginning June 1	Supply			Disappearance				Price
	Beginning stocks	Production	Total	Exports 1/	Domestic	Total	Ending stocks	Minn-eapolis
	--Million pounds--							Cents/lb.
1987/88	2,198	21,981	24,179	0	23,072	23,072	1,107	10.00
1988/89	1,107	15,822	16,929	0	16,188	16,188	741	11.10
1989/90	741	19,143	19,884	0	19,003	19,003	882	10.50
1990/91	882	22,717	23,599	0	22,319	22,319	1,279	10.30
1991/92	1,279	16,146	17,425	0	17,158	17,158	267	10.10
1992/93 2/	267	14,455	14,722	0	14,522	14,522	200	10.00
1993/94 3/	200	7,442	7,642	0	7,492	7,492	150	12.40

1/ Trade data does not distinguish between industrial and edible (canola) exports, therefore all exports were allocated to canola. 2/ Preliminary.
3/ Forecast.

Table 12--Industrial rapeseed oil, supply, disappearance, and price, United States, 1987/88-1993/94

Year beginning June 1	Supply				Disappearance				Price
	Beginning stocks	Production	Imports	Total	Exports 1/	Domestic	Total	Ending stocks	Minn-eapolis
	--Million pounds--								Cents/lb.
1987/88	800	6,785	17,637	25,222	0	22,699	22,699	2,522	23.60
1988/89	2,522	6,858	35,274	44,654	0	40,188	40,188	4,465	25.60
1989/90	4,465	8,184	29,407	42,056	0	37,851	37,851	4,206	27.80
1990/91	4,206	6,960	20,657	31,823	0	28,640	28,640	3,182	24.50
1991/92	3,182	5,705	8,647	17,534	0	15,780	15,780	1,753	22.60
1992/93 2/	1,753	3,707	9,968	15,429	0	13,886	13,886	1,543	24.30
1993/94 3/	1,543	3,390	11,218	16,157	0	14,536	14,536	1,615	

1/ Trade data does not distinguish between industrial and edible (canola) exports, therefore all exports were allocated to canola. 2/ Preliminary.
3/ Forecast.

Table 13--Industrial rapeseed meal, supply, disappearance, and price, United States, 1987/88-1993/94

Year beginning June 1	Supply				Disappearance				Price
	Beginning stocks	Production	Imports	Total	Exports	Domestic	Total	Ending stocks	Minn-eapolis
	--Million pounds--								Cents/lb.
1987/88	300	10,624	0	10,924	0	10,711	10,711	212	168.00
1988/89	212	10,738	0	10,950	0	10,736	10,736	215	177.00
1989/90	215	12,815	0	13,030	0	12,773	12,773	256	149.00
1990/91	256	10,897	0	11,153	0	10,935	10,935	218	145.00
1991/92	218	8,933	0	9,151	0	9,017	9,017	134	151.00
1992/93 1/	134	5,805	0	5,939	0	5,852	5,852	87	155.00
1993/94 2/	87	5,308	0	5,395	0	5,315	5,315	80	160.00

1/ Preliminary. 2/ Forecast.

Table 14--Canola oil prices, Midwest markets, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Cents/pound--							
1989	25.00	25.30	26.40	26.25	25.55	23.44	22.50	22.38	23.00	23.19	25.31	25.60	24.49
1990	26.69	27.50	28.94	29.25	31.15	27.19	25.31	26.90	18.38	24.38	24.63	23.13	26.12
1991	24.00	23.56	24.38	24.88	24.25	23.75	22.90	23.94	24.56	23.05	23.38	22.42	23.76
1992	22.25	21.75	21.75	20.75	22.00	22.31	20.94	20.69	22.90	22.19	24.38	23.08	22.08
1993	24.69	23.81	23.94	23.63	N.A.	N.A.	N.A.	N.A.	24.50	23.38	26.42	29.35	24.96
1994	30.17	30.31	30.50	29.50									

N.A. = Not available.

Source: Milling and Baking News.

Table 15--Castor oil prices, raw No. 1, tanks, Brazilian, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Cents/pound--							
1989	51.00	51.75	51.90	51.50	51.50	51.50	51.50	51.50	41.20	51.50	51.50	53.75	50.84
1990	54.50	53.50	52.60	52.00	51.20	51.00	51.00	51.00	45.00	42.40	39.63	39.63	48.62
1991	39.30	36.00	36.75	37.00	37.00	36.50	35.50	35.00	35.00	35.40	35.00	37.50	36.33
1992	37.50	37.50	37.50	36.00	34.50	34.50	34.50	34.50	34.00	34.00	34.00	34.00	35.21
1993	34.00	32.00	32.00	32.00	37.00	37.00	37.00	37.00	38.50	44.00	44.00	44.00	37.37
1994	44.00	41.75	41.00	41.00									

Source: Chemical Marketing Reporter.

Table 16--Cocoa butter spot prices, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Dollars/pound--							
1989	1.62	1.62	1.72	1.72	1.55	1.45	1.45	1.45	1.35	1.35	1.35	1.35	1.50
1990	1.35	1.30	1.30	1.30	1.30	1.52	1.50	1.50	1.60	1.60	1.60	1.61	1.46
1991	1.61	1.61	1.53	1.53	1.53	1.33	1.22	1.22	1.22	1.22	1.22	1.22	1.37
1992	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.29	1.29	1.29	1.29	1.29	1.25
1993	1.29	1.29	1.35	1.35	1.35	1.35	1.35	1.35	1.40	1.40	1.45	1.45	1.37
1994	1.45	1.45	1.45	1.45	1.45								

Source: Chemical Marketing Reporter.

Table 17--Coconut oil prices, crude, tanks, f.o.b. New York, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Cents/pound--							
1989	26.75	27.63	27.90	28.94	29.90	29.56	28.94	27.75	28.63	27.25	26.35	24.81	27.87
1990	24.31	23.69	22.10	21.63	21.30	20.31	19.16	18.58	18.26	18.18	20.45	20.13	20.67
1991	20.22	20.31	20.50	19.38	19.69	21.69	26.19	25.63	25.63	28.50	31.50	32.38	24.30
1992	39.33	36.00	34.57	34.75	33.56	32.13	29.63	27.31	27.88	26.94	27.00	25.50	31.22
1993	24.94	24.33	23.65	23.25	24.13	24.95	25.35	25.61	24.44	23.88	25.62	33.06	25.27
1994	52.30	30.94	29.56	30.19									

Source: Chemical Marketing Reporter.

Table 18--Edible tallow prices, Chicago, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Cents/pound--							
1989	16.50	16.07	16.25	15.75	16.19	16.00	15.73	15.33	16.50	16.18	N.A.	N.A.	13.37
1990	16.77	17.16	15.46	14.25	14.20	14.28	14.21	10.53	13.76	14.55	15.00	15.28	14.62
1991	15.88	14.28	14.43	14.80	13.02	13.25	13.70	14.61	14.37	14.60	14.09	14.00	14.25
1992	14.05	14.00	14.15	14.28	14.66	15.37	15.87	16.00	16.05	16.88	18.18	17.00	15.54
1993	16.08	15.39	16.07	17.15	17.08	16.03	15.18	16.00	16.21	16.95	16.53	16.50	16.26
1994	16.75	16.50	16.75	16.75									

N.A. = Not available.

Source: Grain and Feed Marketing News.

Table 19--Flaxseed, average price received by farmers, United States, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Dollars/bushel--							
1989	8.34	8.70	8.09	7.78	7.54	6.79	5.90	6.49	7.07	7.09	7.15	7.14	7.29
1990	7.24	7.69	8.03	8.60	8.23	8.31	7.56	5.86	5.36	5.15	5.16	5.15	5.53
1991	5.12	4.80	4.90	4.66	4.33	3.98	3.91	3.69	3.55	3.40	3.31	3.46	3.57
1992	3.39	3.43	3.52	3.53	3.61	3.67	3.70	3.71	4.12	4.09	4.10	4.21	3.94
1993	4.12	4.47	4.54	4.41	4.35	4.44	4.29	3.80	4.25	4.09	4.05	4.18	4.25
1994	4.40	4.55	4.60	4.55									

Source: National Agricultural Statistical Service, USDA.

Table 20--Industrial rapeseed oil prices, refined, tanks, New York, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Cents/pound--							
1989	70.00	70.00	80.25	80.25	80.25	80.25	80.25	80.25	80.25	64.20	80.25	80.25	77.20
1990	81.75	82.25	82.25	82.25	82.25	82.25	82.25	82.25	79.75	77.25	77.25	81.00	81.06
1991	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25
1992	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	67.25	62.25	62.25	62.25	76.00
1993	62.25	62.25	62.25	62.25	55.88	53.75	53.75	53.75	53.75	53.75	53.75	53.75	56.76
1994	53.75	53.75	53.75	53.75									

Source: Chemical Marketing Reporter.

Table 21--Inedible tallow prices, Chicago, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Cents/pound--							
1989	14.90	16.00	14.86	14.60	14.70	15.10	14.48	13.52	14.13	10.94	14.75	14.25	14.35
1990	14.87	14.50	14.47	13.50	13.51	14.01	13.50	10.12	13.50	13.42	14.09	14.50	13.67
1991	14.53	12.91	13.63	13.57	12.25	12.36	12.96	14.00	13.50	13.68	13.08	12.50	13.25
1992	N.A.	12.63	12.68	13.25	13.75	13.98	14.75	15.42	15.25	15.73	16.75	13.52	14.34
1993	15.09	14.69	15.24	15.94	15.00	15.11	14.95	14.58	14.54	14.68	14.50	14.94	14.94
1994	15.25	15.33	15.25	15.00									

N.A. = Not available.

Source: Grain and Feed Marketing News.

Table 22--Jojoba oil prices, 1 metric ton or more, f.o.b. Arizona, 1989-94 1/

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Dollars/kilogram--							
1989	14.18	14.18	14.18	14.18	14.18	14.18	15.25	15.25	15.25	15.25	15.25	15.25	14.72
1990	15.25	20.02	20.02	20.02	20.02	20.02	26.00	26.00	25.00	25.00	24.00	24.00	22.11
1991	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	21.00	15.50	15.50	15.50	21.63
1992	15.50	15.50	15.50	15.50	15.50	15.50	15.50	13.50	13.50	11.99	11.99	11.99	14.29
1993	11.99	11.99	11.99	11.99	12.02	12.02	12.02	12.02	10.03	10.03	10.03	10.03	11.35
1994	10.03	10.03	10.03	9.02	9.02								

1/ Price quotes are the low end of a range.

Source: Chemical Marketing Reporter.

Table 23--Linseed oil prices, tanks, Minneapolis, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Cents/pound--							
1989	41.00	41.00	41.40	42.00	42.00	39.75	39.00	39.00	39.50	40.00	40.00	39.50	40.35
1990	40.00	40.00	41.60	42.00	42.00	43.00	44.00	40.40	39.75	36.80	36.00	36.00	40.13
1991	36.00	36.00	36.00	36.00	36.50	36.00	36.00	36.00	36.00	30.00	30.00	30.00	34.54
1992	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	32.00	32.00	32.00	32.00	28.17
1993	32.00	32.00	32.00	32.00	32.00	28.50	32.00	32.00	32.00	32.00	32.00	32.00	31.71
1994	32.00	32.00	32.00	32.00									

Source: Grain and Feed Marketing News.

Table 24--Linseed meal prices, bulk, 34-percent protein, Minneapolis, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Dollars/ton--							
1989	164.00	151.25	150.00	155.00	156.00	162.50	158.75	161.00	145.00	129.00	126.25	128.75	148.96
1990	132.50	124.50	126.25	133.75	143.00	142.50	136.00	126.25	116.25	133.00	143.75	133.50	132.60
1991	131.00	131.25	120.00	121.00	126.25	134.25	133.00	131.25	116.25	128.00	113.75	127.80	126.15
1992	122.00	124.00	115.00	117.50	120.00	125.00	123.50	126.25	131.00	141.25	152.50	137.40	127.95
1993	136.70	142.50	135.40	125.50	125.00	123.20	133.75	150.00	148.75	147.50	161.80	140.00	139.18
1994	140.00	130.00	126.00	125.00									

N.A. = Not available.

Source: Grain and Feed Marketing News.

Table 25--Palm kernel oil prices, bulk, c.i.f. U.S. ports, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Cents/pound--							
1989	25.00	25.00	23.00	23.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
1990	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00
1991	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
1992	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
1993	23.00	23.00	23.00	23.00	23.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	20.67
1994	19.00	19.00	19.00	19.00	19.00								

Source: Chemical Marketing Reporter.

Table 26--Soybean oil prices, crude, tanks, f.o.b. Decatur, 1989-94

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
						--Cents/pound--							
1989	21.13	21.21	22.11	21.97	22.23	20.75	19.66	18.08	18.77	19.02	19.57	19.11	21.09
1990	19.28	20.27	22.80	23.35	24.72	25.03	24.69	25.05	24.45	22.59	21.05	21.55	22.28
1991	21.56	21.66	22.21	21.50	20.23	19.65	19.05	20.23	20.46	19.57	18.78	18.99	20.98
1992	18.77	18.88	19.74	19.00	20.15	20.71	18.82	17.87	18.28	18.36	20.10	20.52	19.13
1993	21.23	20.72	21.00	21.24	21.15	21.30	24.13	23.46	20.93	23.61	22.98	24.22	22.16
1994	29.91	28.85	29.03	27.94									

Source: The Wall Street Journal.

Table 27--Selected prices for biobased chemicals and derivatives 1/

Item	Unit	Average annual price 2/ 1989	1990	1991	1992	1993
Aluminum stearate, carload	Dollars per pound	1.46	1.46	1.46	1.48	1.54
Anise seed oil, Chinese, drums	Dollars per kilogram	16.30	16.30	16.30	16.30	10.46
Arabic gum, National Formulary, powdered, barrels	Dollars per pound	1.85	1.85	1.85	2.67	3.44
Bacitracin, U.S. Pharmacopeia, nonsterile, 1 billion units or more	MM units	7.80	7.80	7.80	7.80	7.59
Bay oil, National Formulary, 50-55 percent, drums	Dollars per pound	13.50	15.25	24.00	25.50	26.00
Beeswax, refined, bleached, white bricks, 100-pound cartons	Dollars per pound	3.10	3.10	3.10	3.12	3.35
Bergamot oil, Italian	Dollars per kilogram	110.00	107.08	167.25	184.25	64.17
Butyl oleate, distilled, drums, carload, f.o.b. works	Cents per pound	70.00	70.00	70.00	70.00	70.00
Butyl stearate, technical, tanks, f.o.b. works	Cents per pound	55.00	55.00	55.00	55.00	54.75
Calcium gluconate, U.S. Pharmacopeia, powdered, f.o.b. warehouse	Dollars per pound	1.80	1.80	2.44	2.50	2.51
Camphor, U.S. Pharmacopeia, powdered, 50-kilogram drums, 10,000 pounds or more	Dollars per pound	5.50	5.50	5.50	5.50	5.50
Capric acid, commercial, pure, tank delivery	Cents per pound	68.33	76.33	83.00	86.75	92.00
Capryl alcohol, secondary, 98-percent, tank, f.o.b. works	Cents per pound	42.00	43.00	48.00	48.00	48.00
Caprylic acid, commercial, pure, tanks	Cents per pound	72.83	78.33	83.00	90.92	102.00
Carboxymethyl cellulose (CMC), technical, 96-percent minimum, low or medium viscosity, bags, 24,000 pounds, f.o.b. Hopewell, VA	Dollars per pound	1.16	1.39	1.55	1.55	1.55
Carnauba wax, Parnahyba, No. 1, yellow, bags, ton lots	Dollars per pound	2.50	2.50	2.88	3.23	3.50
b-Carotene, tablet grade powder, 10-percent	Dollars per kilogram	70.00	72.51	73.33	81.00	86.00
Casein, acid precipitated, ground, 30-mesh, edible, imported, truckload c.i.f.	Dollars per pound	2.50	2.50	2.50	2.52	2.55
Cedarwood oil, Chinese, drums, cans	Dollars per pound	1.69	1.50	1.55	1.66	1.70
Cellulose acetate, powdered, bags, truckload, delivered east	Dollars per pound	1.50	1.58	1.62	1.94	2.12
Cod oil, refined, bulk, f.o.b. Gloucester, MA	Cents per pound	31.50	36.00	36.00	37.25	39.00
Corn syrup, 42 DE, tanks, f.o.b. works	Cents per pound	11.22	11.64	12.90	12.90	12.90
Cube root, powdered, 5-percent-rotenone basis, 50-pound bags, truckload, works	Dollars per pound	0.60	0.60	1.30	1.30	1.30
Denatured alcohol, ethyl (ethanol), CD18, CD19, tanks, delivered east	Dollars per gallon	2.09	2.11	2.08	2.02	2.02
Dextrin, corn, canary dark, paper bags, carload, works	Cents per pound	31.01	32.00	32.00	32.00	32.00
Dextrose, hydrated, commercial, bags, carload, delivered New York	Cents per pound	25.29	25.50	25.50	25.50	25.50
Dibutyl sebacate, tanks, works	Dollars per pound	1.74	1.79	1.79	1.79	1.79
Diglycol laurate, drums, ton lots	Cents per pound	32.50	32.50	32.50	32.50	3.50
Diglycol stearate, 500-pound drums, truckload	Cents per pound	62.00	62.00	62.00	62.00	62.00
Ethyl vanillin, 25-pound drums, 500 pounds or more	Dollars per pound	13.94	14.50	14.56	14.75	14.75
Fir oil, Canada, drums	Dollars per pound	9.75	9.75	9.75	10.94	12.08
Fructose, crystallized, dry, 50-pound bags, truckload, f.o.b. plant	Cents per pound	90.00	60.25	68.75	39.00	39.00
Furfural, tanks, f.o.b. plant	Cents per pound	75.00	77.33	79.00	79.00	79.00
Gelatin, edible, 100 AOAC test, drums, less truckload, delivered	Dollars per pound	1.50	1.50	1.54	1.68	1.70
Glue, bone, extracted, green, 85 jellygrams, bags, carload	Cents per pound	95.00	95.00	95.00	94.00	89.00
Glycerine, natural, refined, U.S. Pharmacopeia, 99.7-percent, tanks, delivered	Cents per pound	79.00	75.92	64.00	56.63	64.08

See footnotes and definitions at end of table.

--Continued

Table 27--Selected prices for biobased chemicals and derivatives 1/--continued

Item	Unit	Average annual price 2/ 1989	1990	1991	1992	1993
Guar gum, industrial, high viscosity, bags, carload, f.o.b. shipping point	Cents per pound	35.00	35.00	35.00	35.00	35.00
Juniperberry oil, Italian	Dollars per kilogram	95.00	91.83	179.25	228.83	264.00
Karaya gum, No. 1, powdered, drums	Dollars per pound	3.50	3.31	3.25	3.25	3.25
Lactic acid, technical, 88-percent, tankcar, freight equaled	Cents per pound	1.03	1.03	1.03	1.03	1.03
Lanolin, anhydrous, pharmaceutical, 400-pounds drums, works	Dollars per pound	0.90	1.01	1.00	1.25	1.25
Lauric acid, commercial, pure, bags, truckload	Cents per pound	57.67	62.50	57.25	62.38	65.00
Lecithin, unbleached, bulk, less carload, works	Cents per pound	37.00	35.00	29.00	28.00	25.75
Locust bean gum, powdered, bags	Dollars per pound	4.75	4.75	4.75	4.75	4.63
Menhaden oil, bulk, Gulf ports	Cents per pound	11.33	10.94	13.13	15.83	16.54
Menthol, natural, Chinese, drums	Dollars per kilogram	24.50	24.02	18.68	19.45	11.20
Myristic acid, commercial, pure, bags, truckload	Dollars per pound	0.88	0.79	0.67	1.10	1.25
Neatsfoot oil, 20 degrees F, drums, truckload, f.o.b. Philadelphia	Cents per pound	54.00	62.00	70.00	70.83	65.63
1-Octadecanol, synthetic, tanks, f.o.b.	Cents per pound	76.17	92.50	92.50	92.50	92.50
Oiticica oil, liquid, drums	Cents per pound	47.17	48.50	51.00	75.08	80.83
Oleic acid, double distilled (white), tanks	Cents per pound	54.00	54.00	54.00	54.00	60.42
Pectin, high methoxyl	Dollars per pound	3.30	3.30	3.30	4.03	4.75
Pelargonic acid, synthetic, tanks, f.o.b., freight allowed	Cents per pound	97.00	97.00	97.00	97.00	103.50
Pine oil, 80-percent minimum alcohol content, bulk, f.o.b. works	Cents per pound	60.50	68.33	72.00	72.00	76.67
Pyrethrum, purified, 20-percent pyrethrins, drums, works	Dollars per pound	37.50	37.50	37.00	37.00	37.00
Quinine hydrochloride, National Formulary, 1,000-ounce drums, 2,000 ounces or more	Dollars per ounce	2.33	2.30	2.30	2.37	2.50
Quinine sulfate, U.S. Pharmacopeia XVIII, 1,000-ounce drums, 2,000-ounces or more	Dollars per ounce	2.33	2.12	2.10	2.17	2.30
Rose oil, natural, National Formulary, Bulgarian otto, bottles	Dollars per kilogram	7,575	7,600	5,308	5,060	5,060
Rotenone resin, 30-45 percent, 100-pound drums, works	Cents per pound	38.00	38.00	51.00	51.00	51.00
Sandalwood oil, East Indian	Dollars per kilogram	169.58	170.00	197.08	181.67	248.72
Sebacic acid, chemically pure, bags, carload, works	Dollars per pound	1.98	2.05	2.05	2.05	2.05
Sodium lauryl sulfate, 30-percent, drums, truckload, f.o.b. works	Cents per pound	38.33	43.00	43.00	43.00	47.75
Sorbitol, U.S. Pharmacopeia, regular, 70-percent aqueous, drums, carload, f.o.b. shipping point	Cents per pound	39.58	40.17	33.29	33.00	33.00
Stearic acid, single pressed, bulk	Cents per pound	37.00	38.17	36.00	37.42	44.00
Sucrose, refined, white, bags, carload, f.o.b. refinery, east	Cents per pound	35.28	36.00	36.00	36.00	36.00
Sucrose acetate isobutyrate, 90-percent, drums, truckload, delivered	Dollars per pound	1.33	1.33	1.33	1.33	1.33
Sucrose octa-acetate, denaturing grade, 100-pound drums, f.o.b. works	Dollars per kilogram	12.50	12.50	12.50	12.50	12.50
Tall oil, crude, Southeast, tanks, works, freight equaled	Dollars per ton	140.00	135.42	159.17	150.83	119.17
Tallow fatty acids, technical, tanks, delivered	Cents per pound	29.00	29.00	24.88	23.50	23.50
Tannic acid, National Formulary, fluffy, barrels, 1,000-pound lots	Dollars per pound	6.09	6.09	6.09	6.09	6.09
Tragacanth gum, No. 1, ribbons, 100-pound drums	Dollars per pound	36.00	36.00	36.00	36.00	36.83
Turpentine, crude sulfate, tanks, f.o.b. Southeast works	Dollars per gallon	2.05	1.75	1.36	0.88	0.68
Undecylenic acid, 425-pound drums, 5,000 pounds or more, f.o.b. works	Dollars per pound	3.00	3.30	3.30	3.30	3.30
Vanillin, U.S. Pharmacopeia, drums, f.o.b. works	Dollars per pound	7.08	7.25	7.30	7.30	6.90
Xanthan gum, food grade, 100-pound drums, f.o.b. works	Dollars per pound	5.65	5.65	5.65	5.65	5.74

See next page for footnotes and definitions.

1/ Spot and/or list prices from the *Chemical Marketing Reporter* for selected chemicals and related materials on a New York or other indicated basis. These prices do not represent bid, asked, or actual transaction prices. Variations from these prices may occur for differences in quantity, quality, and location.
2/ Some prices are from the low end of a range.

Chemical definitions:
Aluminum stearate is made by reacting aluminum salts with stearic acid for use in paints and varnishes, lubricants and greases, cosmetics, pharmaceuticals, and as a waterproofing agent and cement additive.

Anise seed oil is distilled from anise seed for use in perfumes, flavors, licorice candies, and color photography.

Arabic gum is a dried, water-soluble exudate from the stems of *Acacia senegal* and related species that is used in pharmaceuticals, adhesives, inks, textile printing, cosmetics, and confectionery and food products.

Bacitracin is produced by *Bacillus subtilis* for use as an antibacterial agent and feed supplement.

Bay oil is an essential oil obtained from bay leaves for use in fragrances and flavors.

Beeswax is a byproduct of honey production used for cosmetics and candles.

Bergamot oil is an essential oil used in perfumes.

Butyl oleate is obtained by alcoholysis of olein or esterification of oleic acid with butanol for use in coatings, polishes, and water-proofing compounds, and as a plasticizer for polyvinyl chloride.

Butyl stearate is obtained by alcoholysis of stearin or esterification of stearic acid with butanol for use in polishes, special lubricants, and coatings and as a plasticizer and emollient in cosmetics and pharmaceuticals.

Calcium gluconate is made by the neutralization of gluconic acid, a glucose derivative, with lime for use in vitamin tablets and as a buffer and sequestering agent.

Camphor is obtained by steam distilling camphor tree (*Cinnamomum camphora*) wood for use in medicines, insecticides, and moth and mildew proofings, and as a plasticizer for cellulose nitrate.

Capric acid is a fatty acid obtained from coconut oil that is used as a base for wetting agents and intermediate chemicals.

Capryl alcohol is obtained by distilling sodium ricinoleate, a castor oil derivative, with an excess of sodium hydroxide for solvents, plasticizers, wetting agents, and petroleum additives.

Caprylic acid is a fatty acid obtained from coconut oil for use in synthesizing dyes, drugs, perfumes, antiseptics, and fungicides.

Carboxymethylcellulose is produced by reacting cellulose with sodium chloroacetate for food, cosmetics, paper products, and drilling muds.

Carnauba wax is a hard commercial wax obtained from leaves of *Copernica cerifera* for shoe, furniture, and floor polishes; leather finishes; varnishes; electric-insulating compounds; and carbon paper.

b-Carotene is extracted from carrots and palm-oil concentration for pharmaceuticals, butter and margarine coloring, and a feed and food additive.

Casein is a coagulated and dried milk protein for adhesives and plastics.

Cedarwood oil is an essential oil distilled from *Juniperus virginiana* for perfumes.

Cellulose acetate is made by reacting cellulose from wood with acetic acid for rayon textiles and cigarette filters.

Corn syrup is made by hydrolysis of cornstarch for use as a sweetener, thickener, or bodying agent in soft drinks.

Cube root contains rotenone, which is used in insecticides, flea powders, fly sprays, and moth-proofing agents.

Denatured ethyl alcohol is made by yeast fermentation of carbohydrates or by hydrolysis of ethylene for solvents, cosmetics, and as an oxygenated gasoline additive.

Dextrin is obtained by heating acidified dry starch for adhesives and paper products.

Dextrose is obtained from cornstarch hydrolysis for use in foods and as a fermentation substrate.

Dibutyl sebacate is a sebacic acid ester used in dielectric liquid, cosmetics, and perfumes, and as a plasticizer and rubber softener.

Diglycol laurate is a lauric acid ester used to size and finish textiles, paper, and leather, and as an emulsifying agent for oils and hydrocarbon solvents.

Diglycol stearate is a stearic acid ester used as a emulsifying agent for oils, solvents, and waxes, and a lubricating agent for paper and cardboard.

Ethyl vanillin is chemically modified vanillin from lignin for food flavoring.

Fir oil is steam distilled from *Picea nigra* for perfumes.

Fructose is derived from beet sugar or cornstarch for foods and medicines.

Furfural is obtained by steam distillation of acidified plant materials for polymers and foundry binders.

Gelatin is water extracted from bones and hides for photographic emulsions and food.

Glue (bone) is obtained by steam treatment and water extraction of bones for glue and mineral flotation processes.

Glycerine is a byproduct of splitting or saponification of fats and oils, or made by petrochemical synthesis for cosmetics, food, drugs, and polyurethane polymers.

Guar gum is a water-soluble plant mucilage used in paper coatings, cosmetics, and pharmaceuticals, and as a food thickener and emulsifier.

Juniperberry oil is obtained from the dried fruit of juniper trees for use in gin, liqueurs, and medicines.

Karaya gum is a hydrophilic polysaccharide from Indian trees of the genus *Sterculia* for use in pharmaceuticals, textile coatings, ice cream and other food products, and adhesives.

Lactic acid is obtained by fermenting starch, whey, molasses, etc. for use in cultured dairy products, plasticizers, adhesives, pharmaceuticals, and in dyeing wool.

Lanolin is extracted from wool for cosmetics, leather dressing, and lubricants.

Lauric acid is the major fatty acid in coconut oil (45 to 50 percent), which is used in alkyd resins, wetting agents, soaps, detergents, and cosmetics.

Lecithin is a byproduct of soy oil extraction used as an emulsifying agent and antioxidant in foods.

Locust bean gum is a polysaccharide plant mucilage from seeds of *Ceratonia siliqua* used in cosmetics, textiles sizings and finishes, and drilling fluids, and in foods as a stabilizer, thickener, and emulsifier.

Menhaden oil is obtained from menhaden fish for soaps, rubber compounding, printing inks, animal feed, and leather-dressing lubricants.

Menthol is derived by freezing peppermint oil or hydrogenation of thymol for perfumes, cigarettes, liquors, and chewing gum.

Myristic acid is obtained by fractional distillation of coconut and other vegetable oils for soaps, cosmetics, and synthesis of esters for flavors and perfumes.

Neatsfoot oil is extracted from the feet/hoofs of slaughtered animals for specialty leather dressings.

1-Octadecanol is made by the reduction of stearic acid for perfumes, cosmetics, intermediate chemicals, surfactants, lubricants, and resins.

Oiticica oil is expressed from seeds of the Brazilian oiticica tree for use as a drying oil in paints and varnishes.

Oleic acid is obtained by fractional crystallization from mixed fatty acids for candles, soaps, and synthesis of other surfactants.

Pectin is obtained from citrus fruit rinds for use in jellies, foods, cosmetics, and drugs.

Pelargonic acid is obtained by oxidation of nonyl alcohol or nonyl aldehyde or oxidative cleavage of erucic acid, the dominant fatty acid in crambe and industrial rapeseed oils, for use in lacquers, plastics, pharmaceuticals, synthetic flavors and odors, and flotation agents.

Pine oil is obtained by steam distillation from pine stumps or synthesized from turpentine for household cleansers, coated paper, mineral flotation, and perfume.

Pyrethrum is extracted from chrysanthemum flowers native to Kenya, Ecuador, and Japan for use in household insecticides.

Quinine hydrochloride and quinine sulfate are obtained from cinchona bark for use as a antimalarial agent in medicine and a flavoring in carbonated beverages.

Rose oil is an essential oil from roses used in perfumes and flavorings.

Rotenone resin is extracted from derris and cube root for insecticides, flea powders, fly sprays, and moth-proofing agents.

Sandalwood oil is an essential oil used in fragrances, perfumes, and flavorings.

Sebacic acid is made by high-temperature cleavage of castor oil for use as an intermediate chemical in the manufacture of polymers and plasticizers.

Sodium lauryl sulfate is synthesized from fatty acids for use in toothpaste and as a food additive and wetting agent for textiles.

Sorbitol is obtained by hydrogenation of glucose for foods, cosmetics, and polyester polymers.

Stearic acid is obtained by hydrogenation of oils and fats for lubricating greases, soaps, and lubricants.

Sucrose is obtained from sugar beets and sugarcane for use in foods, soft drinks, pharmaceuticals, and chemical intermediates for detergents.

Sucrose acetate isobutyrate is made by controlled esterification of sucrose with acetic and isobutyric anhydrides for hot-melt coating formulations and extrudable plastics.

Sucrose octa-acetate is used as a plasticizer for cellulose esters and plastics, and in adhesive and coating compounds.

Tall oil (crude) is a byproduct of paper production (chemical pulping) for refining into rosin and fatty acids.

Tallow fatty acids are made from splitting tallow for direct use as lubricants or in greases, and for separation into pure fatty acids.

Tannic acid is extracted from powdered nutgalls with water and alcohol for use in chemicals, tanning, textile mordants and fixatives, and electroplating.

Tragacanth gum is polysaccharides from *Astragalus* bushes for use in pharmaceutical emulsions, adhesives, leather dressing, textile printing and sizing, dyes, and printing inks.

Turpentine (crude sulfate) is obtained by steam distillation of pine gum recovered from pulping softwoods (for paper production), which is used for alpha and beta pinene.

Undecylenic acid is made by destructive distillation of castor oil for perfumes, flavorings, plastics, plasticizers, and lubricant additive.

Vanillin is extracted from vanilla bean or derived from lignin for use in perfumes, flavorings, and pharmaceuticals.

Xanthan gum is a synthetic, water-soluble polymer made by fermentation of carbohydrates for use in drilling fluids, ore floatation, foods, and pharmaceuticals.

Statistics and Analysis from the Source

ERS-NASS periodicals bring you the latest data, statistics and research on commodities, food, the farm and rural America.

NASS' statistical reports estimate production, stocks, inventories, disposition, utilization, and prices of agricultural inputs and commodities, and other items such as labor, farmworkers, and chemical usage.

ERS' Situation and Outlook reports provide both current intelligence and historical data on national food and agricultural developments, and forecast the effects of changing conditions and policies on domestic and international agriculture.

ERS' research periodicals track a wide variety of trends and conditions in the U.S. farm and rural sectors.

To order, call the ERS-NASS order desk toll free 1-800-999-6779 (outside the U.S. and Canada, dial 703-834-0125. VISA and MasterCard accepted.

Title	Issues	Stock #	Price
Statistical Data:			
Agricultural Chemical Usage	2	PCU	$18
Agricultural Prices	12	PAP	29
Agricultural Prices, elect.	12	PAP-BB	29
Broiler Hatchery	54	PBH	70
Broiler Hatchery, electronic	54	PBH-BB	70
Catfish Processing	16	PCF	31
Cattle	12	PCT	29
Chickens and Eggs	15	PEC	36
Cold Storage	14	PCS	33
Cotton Ginnings	14	PCG	28
Crop Production	17	PCP	49
Crop Production, electronic	17	PCP-BB	49
Crop Progress	36	PCR	53
Crop Progress, electronic	36	PCR-BB	53
Dairy Products	13	PDP	29
Egg Products	12	PEP	26
Farm Labor	4	PFL	17
Grain Stocks	4	PGS	18
Hogs and Pigs	4	PHP	17
Hop Stocks	2	PHS	14
Livestock Slaughter	13	PLS	31
Milk Production	13	PMP	26
Noncitrus Fruits & Nuts	2	PNF	17
Peanut Stocks & Processing	12	PPS	26
Potato Stocks	7	PPO	21
Poultry Slaughter	12	PPY	26
Rice Stocks	4	PRS	17
Sheep and Goats	5	PGG	19
Turkey Hatchery	16	PTH	29
Vegetables	6	PVG	20
Situation and Outlook Reports:			
Agricultural Exports	4	AES	17
Agricultural Income & Finance	4	AIS	18
Agriculture & Trade Regionals	6	WRS	20
Agricultural Trade Update	12	FAU	20
Aquaculture	2	AQS	17

Title	Issues	Stock #	Price
Cotton and Wool	12	CWS	$31
Feed	2	FDS	15
Fruit & Tree Nuts	4	FTS	21
Industrial Uses of Ag Materials	2	IUS	17
Livestock, Dairy, Poultry:			
All	32	LDP-A	66
All, electronic	32	LDP-ABB	66
Paper and electronic	64	LDP-P&E	99
Monthly	12	LDP-M	28
Monthly, electronic	32	LDP-MBB	28
Cattle/sheep	5	LDP-CS	22
Cattle/sheep, electronic	5	LDP-CSBB	22
Dairy	5	LDP-D	22
Dairy, electronic	5	LDP-DBB	22
Hog	5	LDP-H	22
Hog, electronic	5	LDP-HBB	22
Poultry	5	LDP-P	22
Poultry, electronic	5	LDP-PBB	22
Oil Crops	2	OCS	15
Rice	3	RCS	18
Sugar & Sweetener	4	SSS	22
Tobacco	4	TBS	19
Vegetables & Specialties	3	VGS	20
Wheat	4	WHS	21
Research and Analysis:			
Agricultural Outlook	11	AGO	42
Economic Indicators of the Farm Sector	4	ECI	19
Food Review	3	NFR	17
Foreign Agricultural Trade of the United States	8	FAT	29
Journal of Agricultural Economic Research	4	JAE	16
Rural Conditions and Trends	2	RCA	13
Rural Development Perspectives	3	RDP	14

United States
Department of Agriculture
1301 New York Avenue, NW
Washington, DC 20005-4789

OFFICIAL BUSINESS
Penalty for Private Use, $300

FIRST CLASS
POSTAGE & FEES PAID
USDA
PERMIT NO. G-145

MOVING? To change your address, send this sheet with label intact, showing new address to: EMS Information, Rm 228, 1301 New York Ave., NW, Washington, DC 20005-4789

☑ Want to Subscribe? ☑ Time to Renew?

Subscribe to *Industrial Uses of Agricultural Materials Situation and Outlook* today! If you already subscribe to this timely periodical, note that expiration information about your subscription appears on the top line of your mailing label. **The expiration information will appear on your mailing label:** For example, 1-IUS-2 means you have TWO issues remaining in your subscription. **Call toll free, 1-800-999-6779,** and tell us whether you want to subscribe or renew, or return this form to: **ERS-NASS, 341 Victory Drive, Herndon, VA 22070.**

Industrial Uses of Agricultural Materials Situation and Outlook

☐ Yes! I want to **start** my subscription.

☐ Yes! I want to **renew** my subscription.

	1 Year
Domestic:	☐ $17.00
Foreign:	☐ $21.25

New subscribers:

Name: ______________________________

Address: ______________________________

City, State, Zip: ______________________________

Daytime phone: (_______)______________________________

Renewals:

ATTACH MAILING LABEL HERE

Payment method:

☐ **Enclosed is $__________.**

Use purchase orders, checks drawn on U.S. banks (and in U.S. funds), cashier's checks, or international money orders. **Make payable to ERS-NASS.** Please do not send cash.

Credit card orders: ☐ **MasterCard** ☐ **Visa** **Total charges $__________.**

Credit card number: | | | | | | | | | | | | | | | | |

Card expiration date: | | |
Month/Year

For *fastest* service, call our toll-free order desk 1-800-999-6779, in the U.S. and Canada; other areas please call 703-834-0125, or FAX this page to 703-834-0110.